IBA

TECHNICAL REVIEW

10

A Broadcasting Engineer's Vade Mecum

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Contents

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IBA

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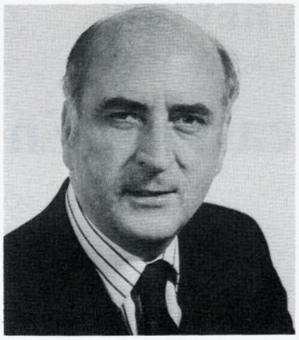
Introduction

by T S Robson, OBE
Director of Engineering
Independent Broadcasting Authority



Throughout the world of science, many individuals necessarily tend to specialise in particular aspects and disciplines; and, with the ever-increasing pace at which technology advances, that tendency becomes more prevalent. Nowadays, this is especially noticeable within the electronics industry. We have the exciting promise of new and improved radio and television equipment, of new systems offering cost savings coupled with increased efficiency, plus the realisation of entirely new concepts such as ORACLE. Every such advancement calls for specialist treatment. Nevertheless, the individual who would keep abreast of current thought and practice in the realm of broadcasting requires also a broad understanding of those other disciplines which link with electronic science. None of us can hope to know it all. Increasingly must we rely on up-to-date technical literature.

The true University of these days
is a collection of books.

Thomas Carlyle

It was with that quotation in mind that in September 1972 we published *IBA Technical Review 2*, entitled 'Technical Reference Book', containing data, specifications and codes of practice as used within the IBA. It was well received throughout the world by broadcasting organisations, colleges of technology, universities and the manufacturing industry. In response to popular demand it was updated and reprinted in July 1974 and again in May 1977; and our latest circulation list shows that, together with other volumes of *IBA Technical Review*, it is read in more than 90 countries. Such world-wide approval of our technical publications, in this period of unprecedented growth within our industry, has encouraged us to produce this companion volume, 'A Broadcasting Engineer's Vade Mecum'—*IBA Technical Review 10*. It contains a yet wider range of facts, figures and formulae, many of them related to our sister disciplines.

There are now many thousands of engineers, technologists and scientists who have found in that 'true University of these days' numerous IBA technical publications. We hope, and believe, they will find this book equally useful.

Units and Dimensions

SI UNITS

QUANTITY	UNIT	SYMBOL	EQUIVALENT
Base units			
Length	metre	m	—
Mass	kilogramme	kg	—
Time	second	s	—
Electric current	ampere	A	—
Temperature	kelvin	K	—
Luminous intensity	candela	cd	—
Supplementary units			
Plane angle	radian	rad	—
Solid angle	steradian	sr	—
Derived units			
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$kg\,m/s^2$
Work, energy, quantity of heat	joule	J	Nm
Power	watt	W	J/s
Electric charge, quantity of electricity	coulomb	C	As
Electric potential, electromotive force	volt	V	W/A
Electric capacitance	farad	F	C/V
Electric resistance	ohm	Ω	V/A
Magnetic flux	weber	Wb	Vs
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd sr
Illumination	lux	lx	lm/m^2

OTHER METRIC UNITS

QUANTITY	UNIT	SYMBOL	EQUIVALENT
Length	angstrom	Å	10^{-10} m
	micron	μm	10^{-6} m
Area	are	a	$10^2\,m^2$
Volume	litre	l	$10^{-3}\,m^3$
Mass	tonne	t	10^3 kg

QUANTITY	UNIT	SYMBOL	EQUIVALENT
Force	dyne	—	10^{-5} N
Pressure	pascal	Pa	$1\,N/m^2$
	bar	bar	$10^5\,N/m^2$
Energy	erg	—	10^{-7} J
Viscosity (dynamic)	centipoise	cP	$10^{-3}\,Ns/m^2$ (= 1 mPa s)
Viscosity (kinetic)	centistokes	cSt	$10^{-6}\,m^2/s$
Electrical conductivity	siemens	S	$1\,\Omega^{-1}$
Magnetic field strength	oersted	—	$10^3/4\pi$ A/m
Magnetomotive force	gilbert	—	$10/4\pi$ A
Magnetic flux density	gauss	—	10^{-4} T
Magnetic flux	maxwell (or line)	—	10^{-8} Wb
Luminance	nit	nt	$1\,cd/m^2$
	stilb	—	$10^4\,cd/m^2$

MULTIPLES AND SUB-MULTIPLES OF UNITS

FACTOR	PREFIX	SYMBOL
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

THE GREEK ALPHABET

A	α	alpha	N	ν	nu
B	β	beta	Ξ	ξ	xi
Γ	γ	gamma	O	o	omicron
Δ	δ	delta	Π	π	pi
E	ϵ	epsilon	P	ρ	rho
Z	ζ	zeta	Σ	σ or ς	sigma
H	η	eta	T	τ	tau
Θ	θ	theta	Y	υ	upsilon
I	ι	iota	Φ	ϕ or φ	phi
K	κ	kappa	X	χ	chi
Λ	λ	lambda	Ψ	ψ	psi
M	μ	mu	Ω	ω	omega

CONVERSION FACTORS

Length

1 thou ($= 10^{-3}$ in)	$= 25{\cdot}40\ \mu$m
1 inch	= 2·540 cm
1 foot (= 12 in)	= 0·3048 m
1 yard (= 3 ft)	= 0·9144 m
1 fathom (= 6 ft)	= 1·829 m
1 furlong (= 220 yards)	= 0·2012 km
1 statute mile (= 5280 ft) (= 8 furlongs)	= 1·609 km
1 UK nautical mile (= 1·15 statute miles) (= 6080 ft)	= 1·853 km
1 international nautical mile	= 1·852 km

Area

1 square inch	$= 645{\cdot}2\ mm^2$
1 square foot	$= 929{\cdot}0\ cm^2$
1 square yard	$= 0{\cdot}8361\ m^2$
1 acre (= 4840 sq yd)	$= 4047\ m^2$
	= 0·4047 ha
1 square mile	$= 2{\cdot}590\ km^2$

Volume

1 cubic inch	$= 16{\cdot}39\ cm^3$
1 fluid ounce	$= 28{\cdot}41\ cm^3$
1 pint	$= 568{\cdot}3\ cm^3$
1 imperial gallon	= 4·546 l
1 US gallon	= 3·785 l
1 cubic foot (= 6·23 imperial gallons)	= 28·32 l
1 cubic yard	$= 0{\cdot}7646\ m^3$

Speed

1 revolution/minute	= 0·1047 rad/s
1 mile/hour (= 88/60 ft/s)	= 0·4470 m/s
1 knot (= 1 nautical mile/h)	= 0·5148 m/s

Mass

1 ounce	= 28·35 g
1 pound (lb)	= 0·4536 kg
1 slug (= 32·17 lb)	= 14·59 kg
1 hundredweight (cwt) (= 112 lb)	= 50·8 kg
1 ton (= 2240 lb)	= 1·016 t

Density

$1\ lb/in^3$	$= 27{\cdot}68\ g/cm^3$
$1\ lb/ft^3$	$= 16{\cdot}02\ kg/m^3$
1 lb/gallon	$= 99{\cdot}78\ kg/m^3$
$1\ ton/yd^3$	$= 1{\cdot}329\ t/m^3$

Moments of Mass

1 lb ft	= 0·1383 kg m
$1\ lb\ ft^2$	$= 421{\cdot}4\ kg\ cm^2$

Force

1 lb force (lbf)	= 4·448 N (standard gravity)
1 poundal (pdl) (= 0·0311 lbf)	= 0·1383 N
1 ton force	= 9·964 kN

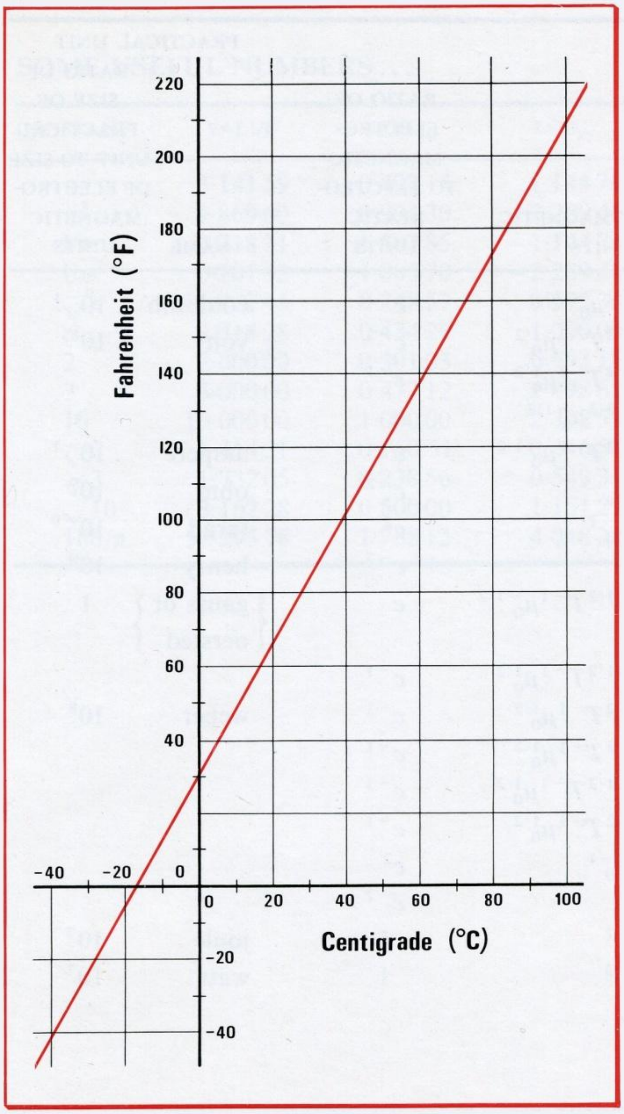
Pressure (or Stress)

$1\ lb/ft^2$	$= 47{\cdot}88\ N/m^2$
$1\ lb/in^2$ (psi)	$= 6{\cdot}895\ kN/m^2$
$1\ ton/ft^2$	$= 107{\cdot}3\ kN/m^2$
$1\ ton/in^2$	$= 15{\cdot}44\ N/mm^2$
1 in Hg (0 °C) (= 0·491 psi)	$= 3{\cdot}386\ kN/m^2$
1 ft H_2O (4 °C) (= 0·434 psi)	$= 2{\cdot}989\ kN/m^2$
1 atmosphere (atm)	= 1·013 bar

Energy

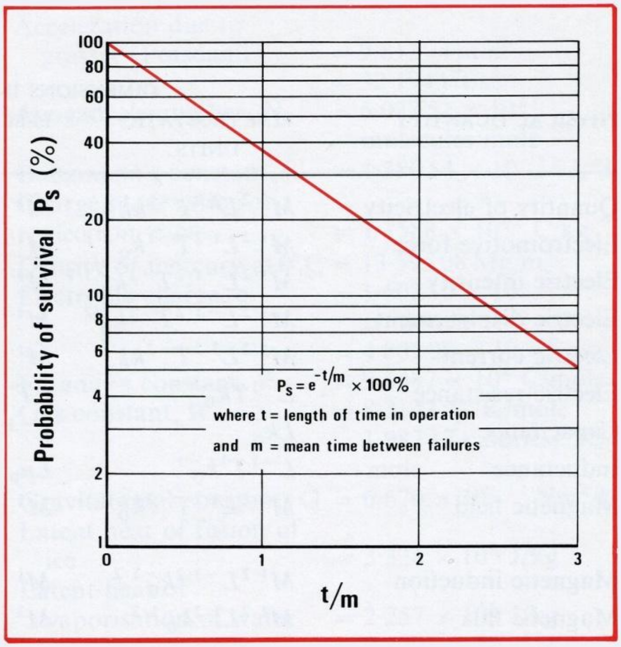
1 ft lbf	= 1·356 J
1 ft pdl	= 42·14 mJ
1 horse-power (= 550 ft lbf/s)	= 745·7 W
1 electron volt (eV)	$= 1{\cdot}602 \times 10^{-19}$ J
1 calorie	= 4·184 J
1 BTU (= 252 cal)	= 1·055 kJ
1 CHU ($\doteqdot \frac{9}{5}$ BTU)	= 1·899 kJ
1 therm (= 10^5 BTU)	= 105·5 MJ
1 BTU/hour	= 0·293 W

TEMPERATURE CONVERTER



PROBABILITY CURVE

Graph showing the probability of survival of an item of equipment against time, normalised to the mean time between failures.



DIMENSIONS OF THE PRINCIPAL ELECTRIC AND MAGNETIC UNITS

PHYSICAL QUANTITY	DIMENSIONS IN ELECTROSTATIC UNITS	DIMENSIONS IN ELECTROMAGNETIC UNITS	RATIO OF ELECTRO-MAGNETIC TO ELECTRO-STATIC UNITS	PRACTICAL UNIT NAME	PRACTICAL UNIT RATIO OF SIZE OF PRACTICAL UNIT TO SIZE OF ELECTRO-MAGNETIC UNITS
Quantity of electricity	$M^{1/2}L^{3/2}T^{-1}k_0^{1/2}$	$M^{1/2}L^{1/2}\mu_0^{-1/2}$	c	coulomb	10^{-1}
Electromotive force	$M^{1/2}L^{1/2}T^{-1}k_0^{-1/2}$	$M^{1/2}L^{3/2}T^{-2}\mu_0^{1/2}$	c^{-1}	volt	10^8
Electric intensity	$M^{1/2}L^{-1/2}T^{-1}k_0^{-1/2}$	$M^{1/2}L^{1/2}T^{-2}\mu_0^{1/2}$	c^{-1}		
Electric displacement	$M^{1/2}L^{-1/2}T^{-1}k_0^{1/2}$	$M^{1/2}L^{-3/2}\mu_0^{-1/2}$	c		
Electric current	$M^{1/2}L^{3/2}T^{-2}k_0^{1/2}$	$M^{1/2}L^{1/2}T^{-1}\mu_0^{-1/2}$	c	ampere	10^{-1}
Electric resistance	$L^{-1}Tk_0^{-1}$	$LT^{-1}\mu_0$	c^{-2}	ohm	10^9
Capacitance	Lk_0	$L^{-1}T^2\mu_0^{-1}$	c^2	farad	10^{-9}
Inductance	$L^{-1}T^2k_0^{-1}$	$L\mu_0$	c^{-2}	henry	10^9
Magnetic field	$M^{1/2}L^{1/2}T^{-2}k_0^{1/2}$	$M^{1/2}L^{-1/2}T^{-1}\mu_0^{-1/2}$	c	gauss or oersted	1
Magnetic induction	$M^{1/2}L^{-3/2}k_0^{-1/2}$	$M^{1/2}L^{-1/2}T^{-1}\mu_0^{1/2}$	c^{-1}		
Magnetic flux	$M^{1/2}L^{1/2}k_0^{-1/2}$	$M^{1/2}L^{3/2}T^{-1}\mu_0^{1/2}$	c^{-1}	weber	10^8
Magnetic moment	$M^{1/2}L^{3/2}k_0^{-1/2}$	$M^{1/2}L^{5/2}T^{-1}\mu_0^{1/2}$	c^{-1}		
Intensity of magnetisation	$M^{1/2}L^{-3/2}k_0^{-1/2}$	$M^{1/2}L^{-1/2}T^{-1}\mu_0^{1/2}$	c^{-1}		
Magnetic pole	$M^{1/2}L^{1/2}k_0^{-1/2}$	$M^{1/2}L^{3/2}T^{-1}\mu_0^{1/2}$	c^{-1}		
Dielectric constant	k_0	$L^{-2}T^2\mu_0^{-1}$	c^2		
Magnetic permeability	$L^{-2}T^2k_0^{-1}$	μ_0	c^{-2}		
Energy	ML^2T^{-2}	ML^2T^{-2}	1	joule	10^7
Rate of working	ML^2T^{-3}	ML^2T^{-3}	1	watt	10^7

where $c = \dfrac{1}{\sqrt{k_0\mu_0}}$ = velocity of light in free space

Useful Constants

SOME USEFUL NUMBERS ...

CONSTANT	VALUE	LOG_{10}	LOG_e
π	3·141 59	0·497 15	1·144 73
π^2	9·869 60	0·994 30	2·289 46
$1/\pi$	0·318 31	$\bar{1}$·502 85	−1·144 73
$1/\pi^2$	0·101 32	$\bar{1}$·005 70	−2·289 46
$\sqrt{\pi}$	1·772 45	0·248 57	0·572 36
e	2·718 28	0·434 29	1·000 00
2	2·000 00	0·301 03	0·693 15
3	3·000 00	0·477 12	1·098 61
10	10·000 00	1·000 00	2·302 59
$\sqrt{2}$	1·414 21	0·150 51	0·346 57
$\sqrt{3}$	1·732 05	0·238 56	0·549 31
$\sqrt{10}$	3·162 28	0·500 00	1·151 29
$180/\pi$	57·295 78	1·758 12	4·048 23

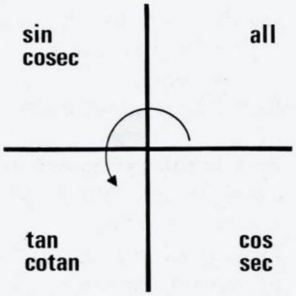
... AND PHYSICAL CONSTANTS

Acceleration due to gravity (Potsdam) = 9·812 74 m/s^2
= 32·1940 ft/s^2
Avogadro's number, N = 6·022 52 × 10^{23} molecules/mole
Boltzmann's constant, k = 1·380 54 × 10^{-23} J/°K
Charge/mass ratio for electron, e/m = 1·7588 × 10^{11} C/kg
Density of mercury at 0°C = 13·595 08 Mg/m^3
Electronic charge, e = 1·602 10 × 10^{-19} coulombs
= 4·802 98 × 10^{-10} esu
Faraday's constant, F = 9·6487 × 10^4 C/mole
Gas constant, R = 8·3143 J/°K/mole
= 1·987 17 calories/°K/mole
Gravitational constant, G = 6·670 × 10^{-11} Nm^2/k
Latent heat of fusion of ice = 3·334 × 10^5 J/kg
Latent heat of vaporisation of water = 2·257 × 10^6 J/kg
Mass of electron, m = 9·1091 × 10^{-31} kg
Mechanical equivalent of heat = 4·1840 joules/calorie
Planck's constant, h = 6·6256 × 10^{-34} Js
$\hbar$ (= $h/2\pi$) = 1·054 50 × 10^{-34} Js
Radius of electron, r = 2·817 77 × 10^{-15} m
Velocity of light in vacuo, c_0 = 2·997 925 × 10^8 m/s
Velocity of sound in dry air at normal pressure and 20°C = 343·6 m/s (1127·3 ft/s)

Mathematical Formulae

TRIGONOMETRICAL FORMULAE

The signs of the trigonometrical ratios depend on the quadrant of the angle, and are positive as indicated in this simple quadrant diagram.



$$\sin^2\theta + \cos^2\theta = 1$$
$$\tan^2\theta + 1 = \sec^2\theta$$
$$1 + \cot^2\theta = \operatorname{cosec}^2\theta$$

$$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B$$
$$\cos(A \pm B) = \cos A\cos B \mp \sin A\sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A\tan B}$$

$$\cot(A \pm B) = \frac{\cot A\cot B \mp 1}{\cot B \pm \cot A}$$

$$\sin 2\theta = 2\sin\theta\cos\theta$$
$$\cos 2\theta = \cos^2\theta - \sin^2\theta$$

$$\tan 2\theta = \frac{2\tan\theta}{1 - \tan^2\theta}$$

$$\sin^2\theta = \tfrac{1}{2}(1 - \cos 2\theta)$$
$$\cos^2\theta = \tfrac{1}{2}(1 + \cos 2\theta)$$

$$\tan\theta = \frac{\sin 2\theta}{1 + \cos 2\theta}$$

If $t = \tan\theta/2$,

$$\sin\theta = \frac{2t}{1 + t^2}$$

$$\cos\theta = \frac{1 - t^2}{1 + t^2}$$

$$\tan\theta = \frac{2t}{1 - t^2}$$

$$\sin\theta/2 = \sqrt{\frac{1 - \cos\theta}{2}}$$

$$\cos\theta/2 = \sqrt{\frac{1 + \cos\theta}{2}}$$

$$\tan\theta/2 = \sqrt{\frac{1 - \cos\theta}{1 + \cos\theta}}$$

$$\sin A + \sin B = 2\sin\left(\frac{A + B}{2}\right)\cos\left(\frac{A - B}{2}\right)$$

$$\sin A - \sin B = 2\cos\left(\frac{A + B}{2}\right)\sin\left(\frac{A - B}{2}\right)$$

$$\cos A + \cos B = 2\cos\left(\frac{A + B}{2}\right)\cos\left(\frac{A - B}{2}\right)$$

$$\cos B - \cos A = 2\sin\left(\frac{A + B}{2}\right)\sin\left(\frac{A - B}{2}\right)$$

$$2\sin A\cos B = \sin(A + B) + \sin(A - B)$$
$$2\cos A\sin B = \sin(A + B) - \sin(A - B)$$
$$2\cos A\cos B = \cos(A + B) + \cos(A - B)$$
$$2\sin A\sin B = \cos(A - B) - \cos(A + B)$$
$$a\sin\theta + b\cos\theta = \sqrt{a^2 + b^2}.\ \sin\left(\theta + \tan^{-1}\frac{b}{a}\right)$$

Solution of Triangles ABC

$$A + B + C = 180^\circ$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} \qquad \text{(sine rule)}$$

$$\left.\begin{aligned} a^2 &= b^2 + c^2 - 2bc\cos A \\ b^2 &= c^2 + a^2 - 2ca\cos B \\ c^2 &= a^2 + b^2 - 2ab\cos C \end{aligned}\right\} \qquad \text{(cosine rule)}$$

$$\frac{a + b}{a - b} = \frac{\tan\left(\frac{A + B}{2}\right)}{\tan\left(\frac{A - B}{2}\right)} \qquad \text{(tangent rule)}$$

If $s = \frac{1}{2}(a+b+c)$,

$$\sin A/2 = \sqrt{\frac{(s-b)(s-c)}{bc}}$$

$$\cos A/2 = \sqrt{\frac{s(s-a)}{bc}}$$

$$\tan A/2 = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)} = \tfrac{1}{2}ab\sin C$$
$$= \frac{a^2 \sin B \sin C}{2\sin A}$$

As in the case of the cosine rule, all of the above relationships can be similarly expressed in terms of the other angles and sides.

EXPONENTIAL AND HYPERBOLIC FUNCTIONS

$$j = \sqrt{-1}$$

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}} = \frac{e^{2x}-1}{e^{2x}+1}$$

$$\sin x = \frac{e^{jx} - e^{-jx}}{2j}$$

$$\cos x = \frac{e^{jx} + e^{-jx}}{2}$$

$$\sinh jx = j\sin x$$
$$\cosh jx = \cos x$$
$$\tanh jx = j\tan x$$

$$\sin jx = j\sinh x$$
$$\cos jx = \cosh x$$
$$\tan jx = j\tanh x$$

$$e^{jx} = \cos x + j\sin x$$
$$e^x = \cosh x + \sinh x$$

$$\sin^{-1} jx = j\sinh^{-1} x$$
$$\cos^{-1} x = -j\cosh^{-1} x$$

$$\sinh^{-1} jx = j\sin^{-1} x$$
$$\cosh^{-1} x = j\cos^{-1} x$$

$$\sinh^{-1} x = \log_e(x + \sqrt{x^2+1})$$
$$\cosh^{-1} x = \log_e(x \pm \sqrt{x^2-1})$$

$$\tanh^{-1} x = \tfrac{1}{2}\log_e \frac{1+x}{1-x} \qquad (\text{where } x^2 < 1)$$

$$(\cos x + j\sin x)^n = \cos nx + j\sin nx$$

(Demoivre's theorem)

For any formula connecting circular functions of general angles, the corresponding formula connecting hyperbolic functions can be obtained by replacing each circular function with the corresponding hyperbolic function provided that the sign of every product, or implied product, of two sines is changed.

(Osborne's Rule)

Hence,

$$\cosh^2 x - \sinh^2 x = 1$$
$$1 - \tanh^2 x = \operatorname{sech}^2 x$$
$$\coth^2 x - 1 = \operatorname{cosech}^2 x$$

$$\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y$$
$$\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y$$

$$\tanh(x \pm y) = \frac{\tanh x \pm \tanh y}{1 \pm \tanh x \tanh y}$$

$$\coth(x \pm y) = -\left(\frac{\coth x \coth y \pm 1}{\coth y \pm \coth x}\right)$$

$$\sinh^2 x = \tfrac{1}{2}(\cosh 2x - 1)$$
$$\cosh^2 x = \tfrac{1}{2}(\cosh 2x + 1)$$

$$\tanh x = \frac{\sinh 2x}{\cosh 2x + 1}$$

$$\sinh x + \sinh y = 2\sinh\left(\frac{x+y}{2}\right)\cosh\left(\frac{x-y}{2}\right)$$

$$\sinh x - \sinh y = 2\cosh\left(\frac{x+y}{2}\right)\sinh\left(\frac{x-y}{2}\right)$$

$$\cosh x + \cosh y = 2\cosh\left(\frac{x+y}{2}\right)\cosh\left(\frac{x-y}{2}\right)$$

$$\cosh x - \cosh y = 2\sinh\left(\frac{x+y}{2}\right)\sinh\left(\frac{x-y}{2}\right)$$

$2\sinh x\cosh y = \sinh(x+y) + \sinh(x-y)$
$2\cosh x\sinh y = \sinh(x+y) - \sinh(x-y)$
$2\cosh x\cosh y = \cosh(x+y) + \cosh(x-y)$
$2\sinh x\sinh y = \cosh(x+y) - \cosh(x-y)$

SERIES

$$1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots = \frac{\pi}{4}$$

$$\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \cdots = \frac{\pi^2}{6}$$

$$\frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \cdots = \frac{\pi^2}{8}$$

$$\frac{1}{1^3} - \frac{1}{3^3} + \frac{1}{5^3} - \cdots = \frac{\pi^3}{32}$$

$$1 + 2 + 3 + \cdots + n = \sum_1^n r = \frac{n(n+1)}{2}$$

$$1^2 + 2^2 + 3^2 + \cdots + n^2 = \sum_1^n r^2 = \frac{n(n+1)(2n+1)}{6}$$

$$1^3 + 2^3 + 3^3 + \cdots + n^3 = \sum_1^n r^3 = \frac{n^2(n+1)^2}{4}$$

Arithmetic

$$a + (a+d) + (a+2d) + \cdots + \{a + (n-1)d\}$$

$$= \frac{n}{2}\{2a + (n-1)d\}$$

$$= \frac{n}{2}(a + l),$$ where l is the last term.

Geometric

$$a + ar + ar^2 + ar^3 + \cdots + ar^{n-1} = \frac{a(1-r^n)}{1-r}.$$

If $|r| < 1$, $\sum^{n=\infty} ar^n = a/(1-r)$.

Binomial For all rational values of n

$$(a+x)^n = a^n + na^{n-1}x + \frac{n(n-1)}{2!}a^{n-2}x^2 + \cdots + \frac{n(n-1)(n-2)\ldots(n-r+1)}{r!}a^{n-r}x^r \ldots$$

N.B. The coefficients of the terms in a binomial expansion are given by the horizontal rows of figures in Pascal's triangle, thus

$n = 0$	1
1	1 1
2	1 2 1
3	1 3 3 1
4	1 4 6 4 1
5	1 5 10 10 5 1
6	1 6 15 20 15 6 1
7	1 7 21 35 35 21 7 1

etc.

Exponential and Logarithmic

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots$$

$$a^x = 1 + x\log_e a + \frac{(x\log_e a)^2}{2!} + \frac{(x\log_e a)^3}{3!} + \cdots$$

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \cdots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \cdots$$

$$\tan x = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \cdots \qquad (|x| < \pi/2)$$

$$\sin^{-1} x = x + \frac{1}{2}\left(\frac{x^3}{3}\right) + \frac{1\times 3}{2\times 4}\left(\frac{x^5}{5}\right) + \frac{1\times 3\times 5}{2\times 4\times 6}\left(\frac{x^7}{7}\right) + \cdots \qquad (|x| < 1)$$

$$\tan^{-1} x = x - \frac{x^3}{3} + \frac{x^5}{5} - \cdots$$

$$\sinh x = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots$$

$$\cosh x = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \cdots$$

$$\tanh x = x - \frac{x^3}{3} + \frac{2x^5}{15} - \frac{17x^7}{315} + \cdots$$

$$\log_e(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots \qquad (|x| < 1)$$

Taylor's Theorem

$$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \cdots$$

Maclaurin's Theorem

$$f(x) = f(0) + xf'(0) + \frac{x^2}{2!}f''(0) + \frac{x^3}{3!}f'''(0) + \cdots$$

Fourier's Series

$$f(x) = \frac{a_0}{2} + a_1 \cos\frac{2\pi x}{T} + a_2 \cos\frac{4\pi x}{T} + \cdots$$

$$+ b_1 \sin\frac{2\pi x}{T} + b_2 \sin\frac{4\pi x}{T} + \cdots \qquad (0 < x < T)$$

where $a_n = \dfrac{2}{T}\displaystyle\int_0^T f(x)\cos\frac{2\pi n x}{T}\,dx$

$$b_n = \frac{2}{T}\int_0^T f(x)\sin\frac{2\pi n x}{T}\,dx.$$

If $f(x) = f(-x)$, f is *even* and $b_n = 0$.
If $f(x) = -f(-x)$, f is *odd* and $a_n = 0$.
If $f(x) = -f\left(x + \dfrac{T}{2}\right)$, f has half-wave symmetry and $a_n = b_n = 0$ for all even values of n.

DIFFERENTIALS

$f(x)$	$f'(x)$
Where u, v and w are functions of x,	
uv	$u\dfrac{dv}{dx} + v\dfrac{du}{dx}$
uvw	$uv\dfrac{dw}{dx} + vw\dfrac{du}{dx} + wu\dfrac{dv}{dx}$
$\dfrac{u}{v}$	$\dfrac{1}{v^2}\left(v\dfrac{du}{dx} - u\dfrac{dv}{dx}\right)$
$f(u,v)$	$\dfrac{\partial f}{\partial u}\dfrac{du}{dx} + \dfrac{\partial f}{\partial v}\dfrac{dv}{dx}$

$f(x)$	$f'(x)$
ax^n	anx^{n-1}
e^x	e^x
e^{ax}	$a\,e^{ax}$
a^x	$a^x \log_e a$
x^x	$x^x(1 + \log_e x)$
$\log_e x$	$1/x$
$\log_a x$	$1/x \log_e a$
$\sin x$	$\cos x$
$\cos x$	$-\sin x$
$\tan x$	$\sec^2 x$
$\operatorname{cosec} x$	$-\cot x \operatorname{cosec} x$
$\sec x$	$\tan x \sec x$
$\cot x$	$-\operatorname{cosec}^2 x$
$\sinh x$	$\cosh x$
$\cosh x$	$\sinh x$
$\tanh x$	$\operatorname{sech}^2 x$
$\operatorname{cosech} x$	$-\coth x \operatorname{cosech} x$
$\operatorname{sech} x$	$-\tanh x \operatorname{sech} x$
$\coth x$	$-\operatorname{cosech}^2 x$
$\sin^{-1}(x/a)$	$(a^2 - x^2)^{-1/2}$
$\cos^{-1}(x/a)$	$-(a^2 - x^2)^{-1/2}$
$\tan^{-1}(x/a)$	$a/(a^2 + x^2)$
$\operatorname{cosec}^{-1}(x/a)$	$-a/x(x^2 - a^2)^{1/2}$
$\sec^{-1}(x/a)$	$a/x(x^2 - a^2)^{1/2}$
$\cot^{-1}(x/a)$	$-a/(a^2 + x^2)$
$\sinh^{-1}(x/a)$	$(a^2 + x^2)^{-1/2}$
$\cosh^{-1}(x/a)$	$\pm(x^2 - a^2)^{-1/2}$
$\tanh^{-1}(x/a)$	$a/(a^2 - x^2)$
$\operatorname{cosech}^{-1}(x/a)$	$\pm a/x(x^2 + a^2)^{1/2}$
$\operatorname{sech}^{-1}(x/a)$	$\pm a/x(a^2 - x^2)^{1/2}$
$\coth^{-1}(x/a)$	$-a/(x^2 - a^2)$

INDEFINITE INTEGRALS

In the following integrals the constant of integration has been omitted.

$f(x)$	$\int f(x)\,\mathrm{d}x$
$x^n \quad (n \neq -1)$	$\dfrac{x^{n+1}}{n+1}$
$(ax+b)^n \quad (n \neq -1)$	$\dfrac{(ax+b)^{n+1}}{a(n+1)}$
x^{-1}	$\log_e x$
$(ax+b)^{-1}$	$\dfrac{1}{a}\log_e(ax+b)$
$\dfrac{x}{ax+b}$	$\dfrac{ax - b\log_e(ax+b)}{a^2}$
a^x	$a^x/\log_e a$
xa^x	$\dfrac{a^x x}{\log_e a} - \dfrac{a^x}{(\log_e a)^2}$
$x\,\mathrm{e}^{ax}$	$\mathrm{e}^{ax}(ax-1)/a^2$
$(a+b\,\mathrm{e}^{cx})^{-1}$	$\dfrac{x}{a} - \dfrac{1}{ac}\log_e(a+b\,\mathrm{e}^{cx})$
$\log_e x$	$x(\log_e x - 1)$
$(\log_e x)^2$	$x[(\log_e x)^2 - 2\log_e x + 2]$
$x^n \log_e ax \quad (n \neq -1)$	$\dfrac{x^{n+1}}{n+1}\left(\log_e ax - \dfrac{1}{n+1}\right)$
$(\log_e ax)^n/x \quad (n \neq -1)$	$(\log_e ax)^{n+1}/(n+1)$
$1/x\log_e x$	$\log_e(\log_e x)$
$(x^2+a^2)^{-1}$	$\dfrac{1}{a}\tan^{-1}(x/a)$
$(x^2-a^2)^{-1} \quad (a^2 < x^2)$	$-\dfrac{1}{a}\coth^{-1}\dfrac{x}{a}$
$(a^2+x^2)^{-1} \quad (x^2 < a^2)$	$\dfrac{1}{a}\tanh^{-1}\dfrac{x}{a}$

$f(x)$	$\int f(x)\,\mathrm{d}x$
$(x^2+a^2)^{1/2}$	$\frac{1}{2}[x(x^2+a^2)^{1/2} + a^2\sinh^{-1}(x/a)]$
$(x^2-a^2)^{1/2}$	$\frac{1}{2}[x(x^2-a^2)^{1/2} - a^2\cosh^{-1}(x/a)]$
$(a^2-x^2)^{1/2}$	$\frac{1}{2}[x(a^2-x^2)^{1/2} + a^2\sin^{-1}(x/a)]$
$(x^2+a^2)^{-1/2}$	$\sinh^{-1}(x/a)$
$(x^2-a^2)^{-1/2} \quad (a^2 < x^2)$	$\pm\cosh^{-1}(x/a)$
$(a^2-x^2)^{-1/2} \quad (x^2 < a^2)$	$\sin^{-1}(x/a)$
$a/x(x^2-a^2)^{1/2} \quad (a^2 < x^2)$	$\sec^{-1}(x/a)$
$\sin x$	$-\cos x$
$\cos x$	$\sin x$
$\tan x$	$\log_e \sec x$
$\operatorname{cosec} x$	$\log_e \tan(x/2)$
$\sec x$	$\log_e(\sec x + \tan x)$
$\cot x$	$\log_e \sin x$
$\sin^2 x$	$\frac{1}{2}(x - \frac{1}{2}\sin 2x)$
$\cos^2 x$	$\frac{1}{2}(x + \frac{1}{2}\sin 2x)$
$\tan^2 x$	$\tan x - x$
$\operatorname{cosec}^2 x$	$-\cot x$
$\sec^2 x$	$\tan x$
$\cot^2 x$	$-(x + \cot x)$
$x\sin x$	$\sin x - x\cos x$
$x\cos x$	$\cos x + x\sin x$
$\sin^{-1} x$	$x\sin^{-1} x + (1-x^2)^{1/2}$
$\cos^{-1} x$	$x\cos^{-1} x - (1-x^2)^{1/2}$
$\tan^{-1} x$	$x\tan^{-1} x - \frac{1}{2}\log_e(1+x^2)$

$f(x)$	$\int f(x)\,dx$
$\sinh x$	$\cosh x$
$\cosh x$	$\sinh x$
$\tanh x$	$\log_e \cosh x$
$\operatorname{cosech} x$	$\log_e \tanh (x/2)$
$\operatorname{sech} x$	$\tan^{-1}(\sinh x)$
$\coth x$	$\log_e \sinh x$
$\sinh^2 x$	$\frac{1}{2}(-x + \frac{1}{2}\sinh 2x)$
$\cosh^2 x$	$\frac{1}{2}(x + \frac{1}{2}\sinh 2x)$
$\tanh^2 x$	$x - \tanh x$
$\operatorname{cosech}^2 x$	$-\coth x$
$\operatorname{sech}^2 x$	$\tanh x$
$\coth^2 x$	$x - \coth x$
$x \sinh x$	$x\cosh x - \sinh x$
$x \cosh x$	$x\sinh x - \cosh x$
$\sinh^{-1} x$	$x\sinh^{-1} x - (x^2 + 1)^{1/2}$
$\cosh^{-1} x$	$x\cosh^{-1} x - (x^2 - 1)^{1/2}$
$\tanh^{-1} x$	$x\tanh^{-1} x + \frac{1}{2}\log_e(1 - x^2)$

The Loudness of Sound

Loudness is the subjective evaluation of the intensity of a sound wave. It corresponds to brightness in the case of light. Being a physiological sensation its measurement in terms of physical values is not simple.

The loudness of a sound depends on the amount of energy contained in a pressure wave, and this in turn is proportional to its $(\text{amplitude})^2$, and also to the $(\text{particle velocity})^2$. It also varies with pitch, or frequency, in as much that the ear has greatest sensitivity in the spectral region between about 1 and 5 kHz.

The unit of loudness is the phon, and the scale of loudness is a comparative one based on zero phon level being taken as the threshold of hearing. By definition this corresponds to a sound pressure level at 1 kHz of $2 \times 10^{-5}\ \mathrm{N/m^2}$ ($= 20\ \mu\mathrm{Pa}$). The frequency of 1 kHz is always taken as the reference frequency for determining loudness in phons; at other frequencies loudness is determined subjectively by comparison with the loudness levels obtained at 1 kHz. Curves of equal loudness for pure tones are shown in Fig. 1.

$$\text{Intensity level} = 10 \log_{10} \frac{I}{I_0} \quad \text{decibels,}$$

where I_0 is the internationally agreed reference intensity of $10^{-12}\ \mathrm{W/m^2}$. Similarly,

$$\text{sound pressure level} = 20 \log_{10} \frac{P}{P_0} \quad \text{decibels (or phons at 1 kHz),}$$

where $P_0 = 2 \times 10^{-5}\ \mathrm{N/m^2}$. For most practical purposes involving plane waves in air these two expressions are almost exactly equivalent, but for other media they may yield results that are significantly different.

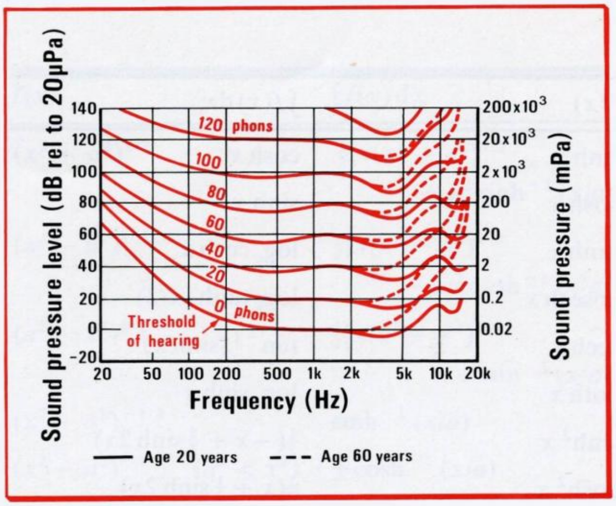


Fig. 1. Equal loudness curves for pure tones. (Robinson and Dadson)

Very high sound pressures in the region of 120 dB produce pain in the ears. Comparatively short periods of exposure to such high levels of sound intensity will cause shifts in the listener's threshold of hearing level which in the first place may be temporary but can become permanent.

Some typically average sound levels are given in the table below.

SOME AVERAGE SOUND LEVELS

SOUND PRESSURE (mPa)	PRESSURE RATIO		INTENSITY RATIO	SOUND LEVEL (dB)	SOURCE OR DESCRIPTION OF TYPICAL SOUND
0·02 (datum)	1	$(= 10^{0})$	1	0	Sound-proof room (threshold of hearing)
0·063	3·16	$(= 10^{0\cdot 5})$	10^{1}	10	Rustle of leaves in a gentle breeze
0·2	10	$(= 10^{1})$	10^{2}	20	A whisper
0·63	31·6	$(= 10^{1\cdot 5})$	10^{3}	30	Quiet conversation
2	100	$(= 10^{2})$	10^{4}	40	Surburban home
6·3	316	$(= 10^{2\cdot 5})$	10^{5}	50	Average conversation
20	1000	$(= 10^{3})$	10^{6}	60	Large shop
63	3160	$(= 10^{3\cdot 5})$	10^{7}	70	Busy city street
200	10 000	$(= 10^{4})$	10^{8}	80	Noisy typing office
630	31 600	$(= 10^{4\cdot 5})$	10^{9}	90	Underground railway
2000	100 000	$(= 10^{5})$	10^{10}	100	Pneumatic drill at 10 ft
6300	316 000	$(= 10^{5\cdot 5})$	10^{11}	110	Prop aircraft taking off
20 000	1 000 000	$(= 10^{6})$	10^{12}	120	Jet aircraft taking off (threshold of pain)

Relationship Between Power, Voltage or Current Ratios, Decibels and Nepers

If the power levels at two points in a transmission system are denoted by P_1 and P_2, then, by definition, the difference in level in bels (B) is $\log_{10} P_1/P_2$. Hence, the corresponding level-difference in decibels (dB) is given by

$$\mathrm{dB} = 10\log_{10}\frac{P_1}{P_2}.$$

If, in addition, the two points under consideration have the same value of impedance, the level-difference in decibels can be obtained from the ratio of the voltages, V_1/V_2, or currents, I_1/I_2, i.e.

$$\mathrm{dB} = 20\log_{10}\frac{V_1}{V_2} = 20\log_{10}\frac{I_1}{I_2}.$$

In all cases where the ratio is less than unity it is usual to take the reciprocal and express the result as a decibel loss.

Alternatively, the neper, by definition, is the natural logarithm of the ratio of two voltages or currents. If the level-difference in nepers is represented by N, then

$$N = \log_e\frac{V_1}{V_2} = \log_e\frac{I_1}{I_2}.$$

To convert decibels to nepers, multiply by 0·1151.
To convert nepers to decibels, multiply by 8·686.

The conversion table shows some numerical values within the range 0·1 to 100 dB.

It has become accepted practice in sound broadcasting to regard a power level of 1 mW in a resistance of 600 ohms, corresponding to a signal level of 0·775 V rms, as an absolute datum (0 dBm). Using this convention, and given a resistive impedance of 600 ohms at each point of measurement, signal levels expressed in dBm (above or below this datum) correspond to definite voltage (or current) *levels* and not merely *ratios*.

Alternatively, especially when dealing with aerials and feeders, it may be more convenient to take 50 ohms as the reference impedance. In this case the voltage scale at datum is lowered by approximately 0·55 V. Both scales are shown in the graph of Fig. 2.

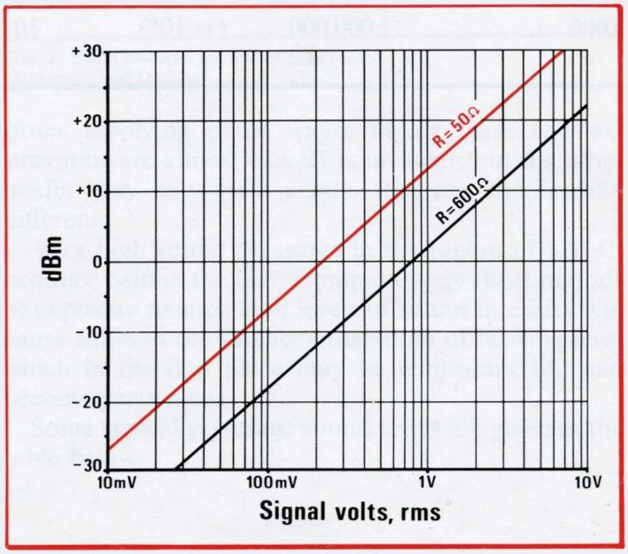


Fig. 2. Graphs showing the relationship between dBm and voltage for 50 and 600 ohm circuits.

DECIBEL CONVERSION TABLE

POWER RATIO	VOLTAGE OR CURRENT RATIO	DECIBELS	NEPERS	POWER RATIO	VOLTAGE OR CURRENT RATIO	DECIBELS	NEPERS
1·0233	1·0116	0·1	0·01	19·953	4·4668	13·0	1·50
1·0471	1·0233	0·2	0·02	25·119	5·0119	14·0	1·61
1·0715	1·0351	0·3	0·03	31·623	5·6234	15·0	1·73
1·0965	1·0471	0·4	0·05	39·811	6·3096	16·0	1·84
1·1220	1·0593	0·5	0·06	50·119	7·0795	17·0	1·96
1·1482	1·0715	0·6	0·07	63·096	7·9433	18·0	2·07
1·1749	1·0839	0·7	0·08	79·433	8·9125	19·0	2·19
1·2023	1·0965	0·8	0·09	100·00	10·000	20·0	2·30
1·2303	1·1092	0·9	0·10	158·49	12·589	22·0	2·53
1·2589	1·1220	1·0	0·12	251·19	15·849	24·0	2·76
1·3183	1·1482	1·2	0·14	398·11	19·953	26·0	2·99
1·3804	1·1749	1·4	0·16	630·96	25·119	28·0	3·22
1·4454	1·2023	1·6	0·18	1000·0	31·623	30·0	3·45
1·5136	1·2303	1·8	0·21	1584·9	39·811	32·0	3·68
1·5849	1·2589	2·0	0·23	2511·9	50·119	34·0	3·91
1·6595	1·2882	2·2	0·25	3981·1	63·096	36·0	4·14
1·7378	1·3183	2·4	0·28	6309·6	79·433	38·0	4·37
1·8197	1·3490	2·6	0·30	10^4	100·00	40·0	4·60
1·9055	1·3804	2·8	0·32	$1{\cdot}5849 \times 10^4$	125·89	42·0	4·83
1·9953	1·4125	3·0	0·35	$2{\cdot}5119 \times 10^4$	158·49	44·0	5·06
2·2387	1·4962	3·5	0·40	$3{\cdot}9811 \times 10^4$	199·53	46·0	5·29
2·5119	1·5849	4·0	0·46	$6{\cdot}3096 \times 10^4$	251·19	48·0	5·52
2·8184	1·6788	4·5	0·52	10^5	316·23	50·0	5·76
3·1623	1·7783	5·0	0·58	$1{\cdot}5849 \times 10^5$	398·11	52·0	5·99
3·5481	1·8836	5·5	0·63	$2{\cdot}5119 \times 10^5$	501·19	54·0	6·22
3·9811	1·9953	6·0	0·69	$3{\cdot}9811 \times 10^5$	630·96	56·0	6·45
5·0119	2·2387	7·0	0·81	$6{\cdot}3096 \times 10^5$	794·33	58·0	6·68
6·3096	2·5119	8·0	0·92	10^6	1000·0	60·0	6·91
7·9433	2·8184	9·0	1·04	10^7	3162·3	70·0	8·06
10·000	3·1623	10·0	1·15	10^8	10 000	80·0	9·21
12·589	3·5481	11·0	1·27	10^9	31 623	90·0	10·36
15·849	3·9811	12·0	1·38	10^{10}	100 000	100·0	11·51

Light Units and Television Camera Photometry

PHOTOMETRIC QUANTITIES

The four photometric quantities and their preferred units in accordance with the SI system are given in the following table.

QUANTITY	UNIT	ABBREVIATION
Luminous intensity	candela	cd
Luminous flux	lumen	lm
Illumination	lux (lm/m^2)	lx
Luminance	nit (cd/m^2)	nt

However, other units have become well established and are likely to remain in use for some considerable time. This is particularly so in the case of luminance and illumination, and for this reason conversion tables are provided showing the various inter-relationships.

Luminous Intensity, *I*

Luminous intensity is a measure of the illuminating power of a light source. A luminous intensity of one candela is defined as a source which emits a total luminous flux of 4π ($= 12{\cdot}56$) lumens uniformly in all directions (i.e. 1 lm/sr).

Luminous Flux, *F*

The luminous flux of a light source is the total amount of light energy, as measured by its ability to produce the sensation of brightness, emitted per second. The unit is the lumen, which is defined as the luminous flux emitted from a source of 1 cd into a solid angle of 1 steradian.

The sensitivity of the eye to light of different wavelengths is not uniform and is represented by the relative luminosity function. Because of this non-uniformity, it is meaningless to quote light powers in terms of watts. The lumen, therefore, is a subjective unit such that at a wavelength of 555 nm one watt of light power corresponds to 680 lm, but at all other wavelengths is proportionally less in accordance with the relative luminosity function, Fig. 1.

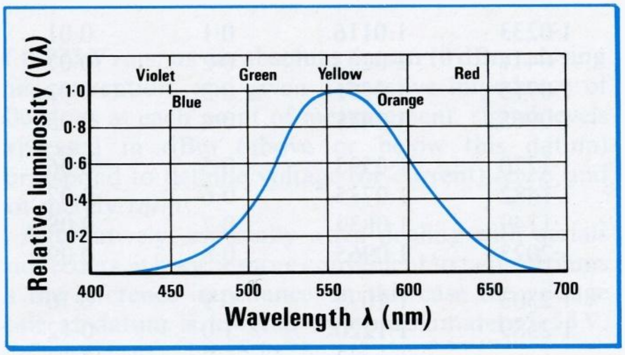


Fig. 1. Relative luminosity function.

Illumination, *E*

The illumination of a surface is the amount of luminous flux falling on unit area. It is measured in terms of lumens per square metre, alternatively known as the metre-candle or lux. Hence, the illumination on the inside surface of a sphere of radius 1 m, produced by a source of 1 cd at its centre is 1 lx. Thus, the luminous flux, F, emanating from a light source of luminous intensity, I, into a solid angle, ω, is given by

$$F = I\omega \quad \text{lumens.}$$

Also, if A is the area of a surface normal to the flux and d is its distance from the source, then $\omega = A/d^2$ and

$$F = \frac{IA}{d^2}.$$

Therefore, the illumination produced on this surface is given by

$$E = \frac{\text{flux}}{\text{area}} = \frac{F}{A} = \frac{I}{d^2} \quad \text{lux.}$$

From Fig. 2 it can be appreciated that the illumination falls off not only with the square of the distance, d, but also with the angle, θ, that the surface makes with the normal to the mean light path. The projected area is thus $A\cos\theta$ and the illumination becomes

$$E = \frac{I\cos\theta}{d^2} \quad \text{lux.}$$

Typical levels of studio illumination for colour television at the present time are between 1000 and

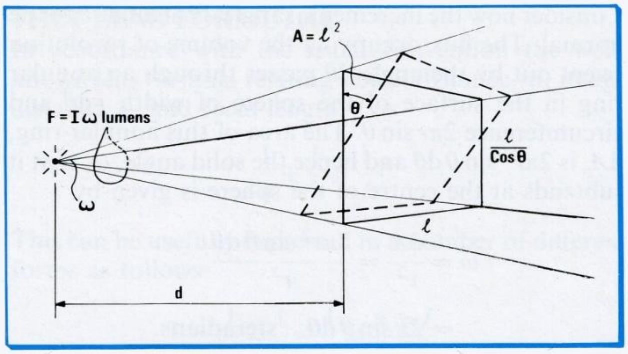


Fig. 2. Illumination from a point source.

2000 lx. Outdoors on a sunny day, levels of 100 000 lx can be experienced.

The unit for very high levels of illumination is the phot which is 1 lm/cm^2 or 10 000 lx. The milliphot is almost equal to a foot-candle or 1 lm/ft^2. Other units include the sea mile-candle and the nox.

ILLUMINATION UNIT		LUX	PHOT	FOOT-CANDLE
1 lux (lm/m^2)	=	1	10^{-4}	$9{\cdot}29 \times 10^{-2}$
1 phot (lm/cm^2)	=	10^4	1	929
1 foot-candle (lm/ft^2)	=	10·76	$10{\cdot}76 \times 10^{-4}$	1

Luminance, L

A surface which is either illuminated or self-luminous will appear more or less bright. Brightness, however, has a subjective connotation and the term luminance is used in the objective sense. In any given direction the luminance of a light-emitting surface is its luminous intensity per unit of projected surface area normal to that direction. There are several units. The internationally preferred metric unit is the nit which represents one candela per square metre of projected surface area, a. Hence,

$$L = \frac{I}{a} \quad \text{nits.}$$

Some surfaces are such that the luminous flux radiated, or reflected, in a direction θ to the normal is directly proportional to cos θ. The light emitted is then a maximum normal to the surface and is zero along the surface. But it appears equally bright in all directions because both reflected light and projected surface area follow the same cosine law. Such a surface is known as a 'lambert' radiator, or reflector, and is described as a uniformly or perfectly diffusing surface. In practice most self-luminous smooth surfaces behave approximately in this manner.

A directional reflecting surface such as a cinema projection screen may exhibit a greater luminance from certain directions than would a perfectly diffusing surface. The ratio between the actual luminance and that of an equally illuminated perfect diffuser is termed the luminance factor. However, a luminance factor greater than unity representing a luminance gain in certain directions is always offset by a factor of less than unity when the screen is viewed from other directions.

Other units include the foot-lambert, which is the luminance of a perfectly diffusing surface emitting, or reflecting, 1 lumen per square foot, the apostilb representing 1 lumen per square metre, and, for brighter sources, the stilb which equals 1 candela per square centimetre. The numerical relationships one with another are shown in the table.

LUMINANCE UNIT		NIT	STILB	APOSTILB	cd/ft^2	LAMBERT	FOOT-LAMBERT
1 nit (cd/m^2)	=	1	10^{-4}	π	$9{\cdot}29 \times 10^{-2}$	$\pi \times 10^{-4}$	0·292
1 stilb (cd/cm^2)	=	10^4	1	$\pi \times 10^{-4}$	929	π	2920
1 cd/ft^2	=	10·76	$1{\cdot}076 \times 10^{-3}$	33·8	1	$3{\cdot}38 \times 10^{-3}$	π
1 apostilb (lm/m^2)	=	$1/\pi$	$1/(\pi \times 10^{-4})$	1	$2{\cdot}96 \times 10^{-2}$	10^{-4}	$9{\cdot}29 \times 10^{-2}$
1 lambert (lm/cm^2)	=	$1/(\pi \times 10^{-4})$	$1/\pi$	10^4	296	1	929
1 foot-lambert or 'equivalent foot-candle' (lm/ft^2)	=	3·43	$3{\cdot}43 \times 10^{-4}$	10·76	$1/\pi$	$1{\cdot}076 \times 10^{-3}$	1

Reflection Co-efficient, ρ

If a surface is perfectly reflecting as well as perfectly diffusing and has an illumination of 1 lux, the light reflected from unit area is 1 lumen and the luminance is 1 apostilb.

In general a surface absorbs some of the incident light and therefore cannot be perfectly reflecting. The reflection co-efficient, ρ, of a surface is defined as

$$\rho = \frac{\text{total light reflected from surface}}{\text{total light incident on surface}},$$

and the luminance of a perfectly diffusing surface of reflectance ρ is given by

$$L = \rho E \quad \text{apostilbs}$$

$$= \frac{\rho E}{\pi} \quad \text{nits.}$$

Typical values of ρ are snow 0·93, soil 0·32, black velvet 0·01. It can be seen that all photometric units are derived from the lumen.

However, the absolute quantitative value of the lumen is derived from the nit which has a magnitude such that the luminance of a black body at the temperature of solidifying platinum is 600 knt.

A Lambert Surface as a Source of Illumination

The total flux emitted from a lambert surface can be determined by considering the radiation from an element of surface, ds. Because the surface is perfectly diffusing, the flux from it will radiate in all directions and so can be regarded as passing through a hemisphere of radius r and centre ds, see diagram.

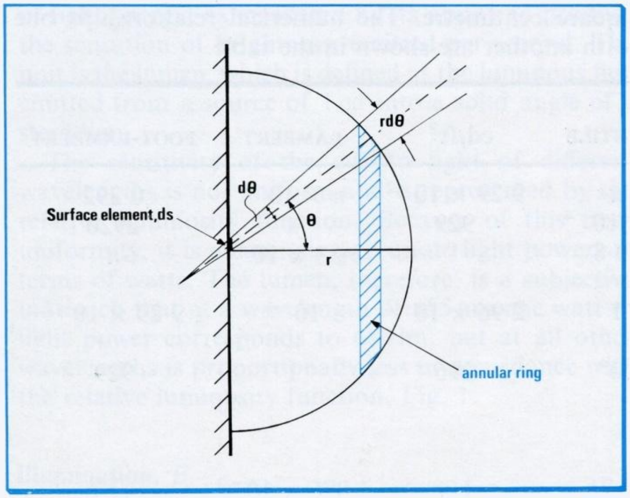


Fig. 3. Illumination of a solid angle by a lambert surface.

Consider now the incremental angle dθ at angle θ to the normal. The flux occupying the volume of revolution swept out by the angle dθ passes through an annular ring in the surface of the sphere of width $r\,\mathrm{d}\theta$ and circumference $2\pi r \sin\theta$. The area of this annular ring, dA, is $2\pi r^2 \sin\theta\,\mathrm{d}\theta$ and hence the solid angle, ω, that it subtends at the centre of the sphere is given by

$$\omega = \frac{\mathrm{d}A}{r^2} = \frac{2\pi r^2 \sin\theta\,\mathrm{d}\theta}{r^2}$$

$$= 2\pi \sin\theta\,\mathrm{d}\theta \quad \text{steradians.}$$

For a lambert surface the luminous intensity, i.e. the flux per steradian, in a given direction falls as the cosine of the angle to the normal. Therefore, if the luminous intensity of the whole surface in the direction of the normal is I, then at angle θ it will be $I\cos\theta$ and for the small area ds

$$\text{intensity} = \frac{I\cos\theta\,\mathrm{d}s}{s} \quad \text{lumens/steradian (= candelas).}$$

But I/s is the luminance of the surface in the direction of the normal. Let this equal L nits, then the above expression becomes

$$\text{intensity of small area, } \mathrm{d}s = L\cos\theta\,\mathrm{d}s \quad \text{candelas.}$$

Now, flux equals intensity $\times$ solid angle. Therefore, the flux, dF, at angle θ to the normal passing through the elemental annular ring in the surface of the hemisphere from a lambert surface of luminance L nits is

$$\mathrm{d}F = L\cos\theta\,\mathrm{d}s \times 2\pi\sin\theta\,\mathrm{d}\theta \quad \text{lumens.}$$

Hence the total light emitted into a cone of semi-vertical angle θ is

$$F = \int_0^\theta 2\pi L\,\mathrm{d}s \sin\theta\cos\theta\,\mathrm{d}\theta$$

$$= \pi L\,\mathrm{d}s \sin^2\theta \quad \text{lumens.} \quad \ldots \quad (1)$$

Putting $\theta = 90°$, the total flux emitted from the surface in all directions is shown to be $\pi L\,\mathrm{d}s$ lumens.

As flux per unit area (in square metres) equals luminance in apostilbs, the luminance of the surface is

$$\frac{\pi L\,\mathrm{d}s}{\mathrm{d}s} = \pi L \quad \text{apostilbs.}$$

Thus, a luminance of L nits for a lambert surface is equivalent to πL apostilbs.

THIN LENS FORMULAE

In accordance with the usual convention the well-known lens formula relating object distance, u, image distance, v, and focal length, f, is

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}.$$

This can be usefully expressed in a number of different forms as follows:

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{u-f}{uf}$$

$$\therefore \qquad v=\frac{uf}{u-f}. \qquad \ldots \ldots \ldots \quad (2)$$

Now, the magnification factor,

$$m=\left|\frac{v}{u}\right|,$$

and by substituting v from (2),

$$m=\frac{uf}{u(u-f)}=\frac{f}{u-f}$$

and

$$m+1=\frac{f+u-f}{u-f}=\frac{u}{u-f}.$$

Substituting this in (1) gives

$$v=f(m+1). \qquad \ldots \ldots \ldots \quad (3)$$

IMAGE ILLUMINATION

When the object distance is large the amount of light traversing an optical system is determined by the diameter of the entrance pupil of the lens and is usually expressed in terms of the aperture or f-number.

This is defined as

$$f\text{-number}=\frac{\text{focal length of lens}}{\text{diameter of entrance pupil}}.$$

Therefore, for a given focal length of lens, the greater the f-number the smaller the diameter, or aperture, and the lower the sensitivity.

Lenses are usually specified by their focal length and maximum aperture, i.e. the f-number with the iris wide open. The amount of light traversing a lens is obviously proportional to its area and hence the square of the diameter. The calibration of a lens iris is in f-numbers which, being inversely proportional to the diameter, advance in $\sqrt{2}$ steps, or stops as they are called, and successively halve the light level. For example, the light entering a lens system is halved by adjusting its iris one stop from $f/4$ to $f/5{\cdot}6$, and doubled by opening the iris one stop from $f/4$ to $f/2{\cdot}8$.

Photo-cathode Illumination

From the result obtained at (1) the flux, F_0, emitted into the solid angle at O, see diagram, from a luminous surface of area ds_0 and luminance L nits is given by the formula,

$$F_0=\pi L\, ds_0 \sin^2\theta_0 \quad \text{lumens}.$$

If the transmission factor of the lens is t, then the flux falling on the image plane at P is

$$F_p=\pi L t\, ds_0 \sin^2\theta_0 \quad \text{lumens}$$

and the illumination, E, of the image (= flux/area) is given by

$$E=\frac{\pi L t\, ds_0 \sin^2\theta_0}{ds_p} \quad \text{lux}.$$

But

$$\frac{ds_0}{ds_p}=\frac{1}{m}=\frac{u^2}{v^2},$$

and for long object distances (i.e. small angles) $\sin^2\theta_0=d^2/4u^2$ where d is the lens diameter,

$$\therefore \qquad E=\frac{\pi L t d^2}{4v^2} \quad \text{lux}.$$

Substituting $v=f(m+1)$ from (3) above,

$$E=\frac{\pi L t d^2}{4f^2(m+1)^2}.$$

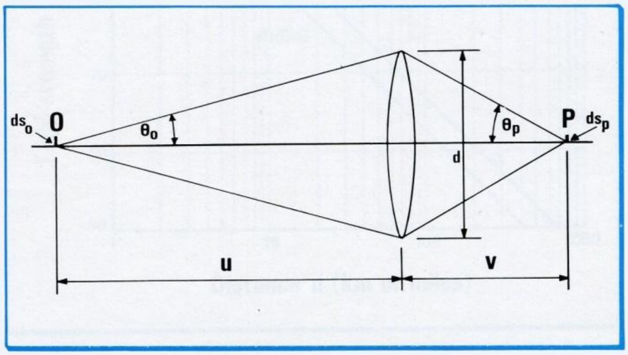


Fig. 4. Photo-cathode illumination.

But

$$\frac{f}{d} = f\text{-number } (f/),$$

$$\therefore \qquad E = \frac{\pi L t}{4(f/)^2(m+1)^2} \quad \text{lux},$$

or if L is quoted in apostilbs instead of nits, then

$$E = \frac{Lt}{4(f/)^2(m+1)^2} \quad \text{lux}.$$

For large values of u, $m \to 0$, and E approximates to

$$E = \frac{Lt}{4(f/)^2} \quad \text{lux}. \qquad \ldots \ldots \ldots \quad (4)$$

Using this formula it is a simple matter to calculate the required scene illumination if the pick-up tube sensitivity and output level are known.

SIGNAL CURRENT

The sensitivity, s, of a camera tube is usually specified in microamps per lumen, and image illumination in lumens per square metre or lux. Therefore, the signal current, i, is given by

$$i = E_T a s \quad \text{amps},$$

where E_T = target illumination in lux
a = target area in square metres
and s = camera tube sensitivity in amps per lumen.

As a typical example, a plumbicon will have a target sensitivity of 300 μA/1m and a target area of 2·18 cm^2. If the incident illumination on the scene is 500 lux, the scene reflectance is 60 per cent and the lens aperture and transmission factor are $f/4$ and 0·9 respectively, the signal current can be calculated as follows. Using (4) above

$$E_T = \frac{Lt}{4(f/)^2} \quad \text{lux},$$

where $L = E_s\rho$, in which
E_s = scene illumination
and ρ = scene reflectance factor

$$\therefore \qquad E_T = \frac{E_s \rho t}{4(f/)^2}.$$

Now,

$$i = E_T a s \quad \text{amps}$$

$$= \frac{E_s \rho t a s}{4(f/)^2}$$

$$= \frac{500 \times 0{\cdot}6 \times 0{\cdot}9 \times (2{\cdot}18 \times 10^{-4}) \times (300 \times 10^{-6})}{4 \times 4^2}$$

$$= \frac{5 \times 6 \times 9 \times 2{\cdot}18 \times 3 \times 10^{-9}}{6{\cdot}4} \quad \text{amps}$$

$$= 276 \quad \text{nA}.$$

Fundamentals of Propagation

An electromagnetic wave consists of two component fields, an electric field of strength E volts/metre and a magnetic field of strength H amps/metre. These fields are mutually perpendicular and the plane in which they are contained is normal to the direction of propagation of the wave. The energy contained in each field is the same and is given by

$$\tfrac{1}{2}ee_0E^2 = \tfrac{1}{2}\mu\mu_0H^2 \quad \text{watts/metre}^2,$$

where $$e_0 = \frac{10^{-9}}{36\pi}$$

and $$\mu_0 = 4\pi 10^{-7}.$$

For free space e, the relative permittivity, and μ, the relative permeability, are both unity.

From the above,

$$\frac{E}{H} = 120\pi$$

$$\simeq 377 \quad \text{ohms}$$

and this is known as the characteristic impedance of free space.

The energy contained in each square metre of wavefront is

$$\frac{E^2}{120\pi} \quad \text{or} \quad 120\pi H^2 \quad \text{watts/metre}^2.$$

If a power of P watts be applied to an isotropic radiator the electric field strength resulting at a distance of d metres is

$$E = \frac{\sqrt{30P}}{d} = \frac{5{\cdot}48\sqrt{P}}{d} \quad \text{volts/metre},$$

but if the isotropic radiator is replaced by a half-wavelength dipole then the field strength at any point in the direction of maximum radiation is given by

$$E = \frac{7{\cdot}014\sqrt{P}}{d} \quad \text{volts/metre}.$$

In practice, it is more usual to express the power, P, in kilowatts, the distance, d, in kilometres and the field strength in microvolts/metre, in which case the expression becomes

$$E = \frac{2{\cdot}218 \times 10^5\sqrt{P}}{d} \quad \text{microvolts/metre},$$

or alternatively

$$E = 106{\cdot}9 + 10\log P - 20\log d \quad \text{dB rel. to } 1\mu\text{V/m}.$$

If the distance, d, is measured in miles this latter expression is modified to

$$E = 103 + 10\log P - 20\log d \quad \text{dB rel. to } 1\,\mu\text{V/m}.$$

A graph of free-space field strength against distance from a power source of 1 kW erp is shown in Fig. 1.

Effective radiated power (erp) is defined as that power which must be radiated from a reference aerial in order to produce a given field strength at a given point located in the direction of maximum radiation. The half-wave dipole is usually taken as the reference aerial.

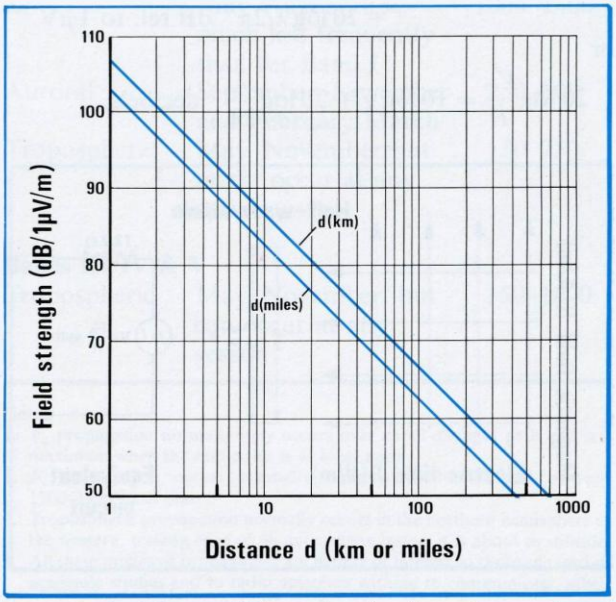


Fig. 1. Graph of free-space field strength against distance from a radiator of 1 kW erp.

If any other aerial is used in place of the reference aerial it is said to have a power gain, G, defined by the relationship

$$G = \frac{\text{power supplied to reference aerial}}{\text{power supplied to aerial under consideration}},$$

where the powers in each case result in the same field strength at any given point. The gain is usually quoted for the direction of maximum radiation of the aerial as both gain and erp vary with direction.

Receiving Aerials

A half-wavelength dipole placed in an electromagnetic wavefront of E volts/metre with its length parallel to the electric field, may be considered as a voltage generator of $\lambda E/\pi$ volts and having an internal impedance of 73·2 ohms, see Fig. 2. Maximum power is therefore available with the aerial terminated in 73·2 ohms and in this condition the terminated voltage, V_T, is $\lambda E/2\pi$. Hence, $V_T/E = \lambda/2\pi$, a term which is sometimes referred to as the dipole aperture factor. The relationship between V_T/E and frequency is shown in Fig. 3.

The receiving aerial may also have a power gain, g, in which case V_T becomes $(\lambda/2\pi)E\sqrt{g}$ volts. Alternatively, if decibel notation is used and E is given in μV/m, then

$$20\log V_T = 20\log E + 10\log g + 20\log\lambda/2\pi \quad \text{dB rel. to } 1\,\mu\text{V},$$

or

$$20\log\frac{V_T}{E} = 10\log g + 20\log\frac{\lambda}{2\pi} \quad \text{decibels.}$$

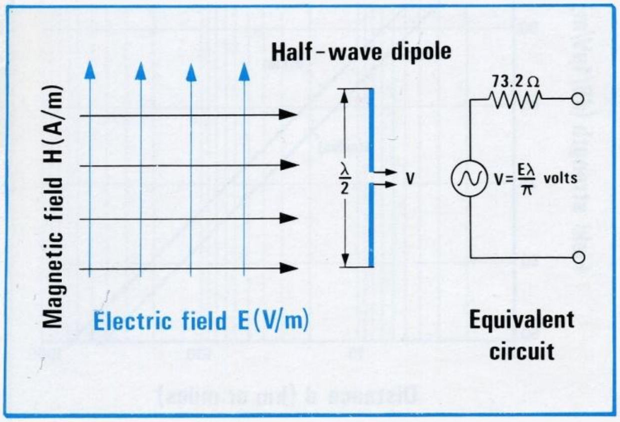


Fig. 2. An electromagnetic wave and its simple equivalent circuit. With the usual conventions for the component fields, the wave shown here would be moving into the paper.

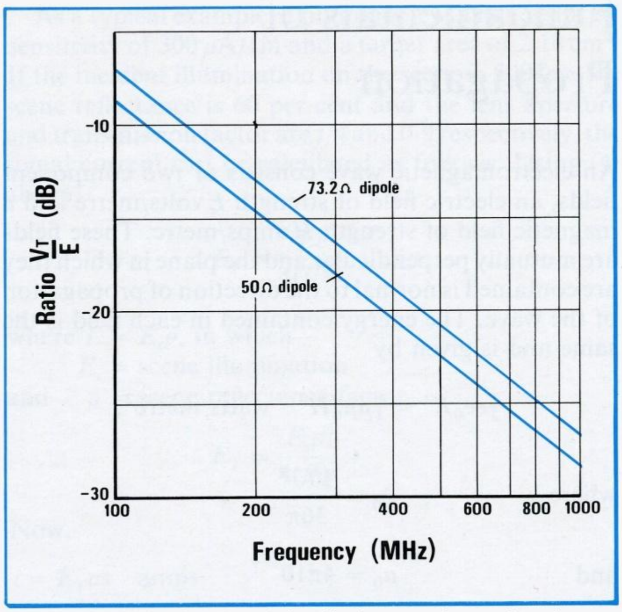


Fig. 3. Graph showing the relationship between the terminated output voltage, V_T, of a correctly orientated half-wavelength dipole in a field strength of E volts/metre.

In practice aerials are often constructed to have impedances other than 73·2 ohms. Such an aerial may be considered as a thin dipole of 73·2 ohms impedance connected through a perfect matching transformer. For a 50 ohm aerial, as is commonly used, the voltage across the terminals will therefore be less in the ratio $\sqrt{50/73{\cdot}2}$, or $-1{\cdot}6$ dB. Thus, for a 50 ohm aerial of gain, g, the above expression becomes

$$20\log\frac{V_T}{E} = 10\log g + 20\log\frac{\lambda}{2\pi} - 1{\cdot}6 \quad \text{decibels.}$$

The power supplied to a matched load by a receiving aerial of gain g is

$$g\frac{V_T^2}{73{\cdot}2} = g\frac{\lambda^2 E^2}{4\pi^2 73{\cdot}2} \quad \text{watts.}$$

This is equivalent to the power contained in an area of A square metres of the wavefront where

$$\frac{AE^2}{120\pi} = \frac{g\lambda^2 E^2}{4\pi^2 73{\cdot}2},$$

i.e.

$$A = \frac{30\lambda^2 g}{73{\cdot}2\pi},$$

which is known as the aperture of the aerial.

Service Areas

For television, a viewer is considered to have an adequate signal if, using an average receiving aerial system, it is possible to obtain a picture with no impairment worse than that which might be described as falling between 'perceptible but not annoying' and 'slightly annoying'. The principal impairments which limit a service are signal/noise ratio, multipath interference (ghosting) and co-channel interference.

Signal/noise ratios which are considered to meet the impairment level for a television service are as shown below. The field strength indicated is that which will yield the signal/noise performance without the use of an above-average aerial system.

	SIGNAL/NOISE RATIO (dB)	FIELD STRENGTH ($dB/1\mu V/m$)
System G, Band I	35	44
System G, Band III	35	54
System I, Band IV	39	64
System I, Band V	39	70

For non-continuous interference caused by occasional tropospheric propagation, the ratio between a wanted and unwanted signal at the input of a television receiver which will produce an impairment not worse than the amount permitted is taken as being 45 dB for cases where the carrier frequencies are nominally the same (± 500 Hz), and 30 dB where they differ by an amount equal to $\pm 5/3$ or $\pm 10/3$ of the line frequency. For continuous interference, these figures are each increased by an amount such that the picture impairment becomes 'perceptible but not annoying'.

In the case of radio, service area limits are determined not by the level of internal receiver noise but by that of external man-made noise in the form of interference either from other transmissions or from electric plant. The field strength limits are therefore related to the probable level of interference which might exist for some portion of the time (usually 5 per cent). For the ILR mf service the IBA works to a field strength contour of 3 mV/m, whereas for the vhf service the limit is 1 mV/m (60 dB rel. 1 μV/m).

In order to improve the reception for listeners using portable receivers or car radios, all IBA vhf sound transmissions are of mixed polarisation. The polarisation is usually circular but at some stations slant polarisation is used. In either case, satisfactory monophonic reception is obtainable using a simple 'whip' aerial; however, for satisfactory stereo reception a roof-mounted directional aerial is generally required.

MODES OF PROPAGATION AT VHF AND UHF WHICH CAN BE RESPONSIBLE FOR INTERFERENCE

MODE	PERIODS OF MOST FREQUENT OCCURRENCE	RANGE OVER WHICH PHENOMENON OCCURS (km)
Band I		
Ionospheric, F_2	October/November and February/March during years of maximum sun-spot activity	2200–4000
E_s	May–August and December/January	500–2400
Auroral	September–November and February/March	200–800
Tropospheric	May–November, but might occur at any season	150–500
Band II		
E_s	May–August, but much less frequently than for Band I	1000–2400
Auroral	September–November and February/March	250–800
Tropospheric	May–November but might occur at any season	150–750
Bands III IV & V		
Tropospheric	May–November, but can occur at any season	150–1000

Notes

1. F_2 propagation normally only occurs over an all-daylight path and is a maximum when the mid-point is at local noon.
2. E_s propagation occurs normally between 0900–1200 and between 1700–1900 local time.
3. Tropospheric propagation normally occurs in the northern hemisphere at the western, trailing edge of an anticyclone just as it is about to subside.
4. All these modes of propagation are mainly of interest to those engaged in academic studies and to radio amateurs wishing to communicate, albeit temporarily, over long distances. In general they are only of nuisance value to broadcasting in that, during the periods indicated, they can result in interference from distant stations.

The Frequency Spectrum and Broadcasting Channels

THE UK BROADCASTING BANDS

Low frequency (long wave)	(lf)	160–225 kHz	(1875–1176 m)	AM radio
Medium frequency (medium wave)	(mf)	525–1605 kHz	(571–187 m)	
Band I	(vhf)	41–68 MHz	(channels 1 to 5)	405-line black-and-white television
Band II	(vhf)	88–97·6 MHz		FM radio
Band III	(vhf)	174–216 MHz	(channels 6 to 13)	405-line black-and-white television
Band IV	(uhf)	470–582 MHz	(channels 21 to 34)	625-line colour/black-and-white television
Band V	(uhf)	614–854 MHz	(channels 39 to 68)	

TELEVISION CHANNELS, NOMINAL CARRIER FREQUENCIES AND WAVELENGTHS

	VISION			SOUND
CHANNEL NO.	FREQUENCY (MHz)	WAVELENGTH (m)	WAVELENGTH (ft)	FREQUENCY (MHz)
Band I				
1	45·00	6·6621	21·8571	41·50
2	51·75	5·7931	19·0062	48·25
3	56·75	5·2827	17·3317	53·25
4	61·75	4·8549	15·9283	58·25
5	66·75	4·4913	14·7351	63·25
Band III				
6	179·75	1·6678	5·4719	176·25
7	184·75	1·6227	5·3238	181·25
8	189·75	1·5799	5·1835	186·25
9	194·75	1·5394	5·0504	191·25
10	199·75	1·5008	4·9240	196·25
11	204·75	1·4642	4·8038	201·25
12	209·75	1·4293	4·6893	206·25
13	214·75	1·3960	4·5801	211·25
Band IV				
21	471·25	0·6362	2·0872	477·25
22	479·25	0·6255	2·0523	485·25
23	487·25	0·6153	2·0186	493·25
24	495·25	0·6053	1·9860	501·25
25	503·25	0·5957	1·9544	509·25
26	511·25	0·5864	1·9239	517·25
27	519·25	0·5774	1·8942	525·25
28	527·25	0·5686	1·8655	533·25
29	535·25	0·5601	1·8376	541·25
30	543·25	0·5518	1·8105	549·25
31	551·25	0·5438	1·7843	557·25
32	559·25	0·5361	1·7587	565·25
33	567·25	0·5285	1·7339	573·25
34	575·25	0·5212	1·7098	581·25

	VISION			SOUND
CHANNEL NO.	FREQUENCY (MHz)	WAVELENGTH (m)	WAVELENGTH (ft)	FREQUENCY (MHz)
Band V				
39	615·25	0·4873	1·5987	621·25
40	623·25	0·4810	1·5781	629·25
41	631·25	0·4749	1·5581	637·25
42	639·25	0·4690	1·5386	645·25
43	647·25	0·4632	1·5196	653·25
44	655·25	0·4575	1·5011	661·25
45	663·25	0·4520	1·4830	669·25
46	671·25	0·4466	1·4653	677·25
47	679·25	0·4414	1·4480	685·25
48	687·25	0·4362	1·4312	693·25
49	695·25	0·4312	1·4147	701·25
50	703·25	0·4263	1·3986	709·25
51	711·25	0·4215	1·3829	717·25
52	719·25	0·4168	1·3675	725·25
53	727·25	0·4122	1·3525	733·25
54	735·25	0·4077	1·3377	741·25
55	743·25	0·4034	1·3233	749·25
56	751·25	0·3991	1·3092	757·25
57	759·25	0·3949	1·2955	765·25
58	767·25	0·3907	1·2819	773·25
59	775·25	0·3867	1·2687	781·25
60	783·25	0·3828	1·2558	789·25
61	791·25	0·3789	1·2431	797·25
62	799·25	0·3751	1·2306	805·25
63	807·25	0·3714	1·2184	813·25
64	815·25	0·3677	1·2065	821·25
65	823·25	0·3642	1·1947	829·25
66	831·25	0·3607	1·1832	837·25
67	839·25	0·3572	1·1720	845·25
68	847·25	0·3538	1·1609	853·25

Notes

1. Frequencies for each channel are nominal, and polarisation is either horizontal or vertical.
2. Offset operation is used on uhf and vhf: on uhf it is either 0, + 5/3, or − 5/3 of line frequency: on vhf non-standard multiples of 1/12 of line frequency are used.
3. Carrier frequency tolerances on uhf are + or − 500 Hz. For vhf, tolerances are + or − 2·5 Hz/10^6 of operating frequency.

UHF RECEIVING AERIALS

CHANNELS	GROUP	COLOUR CODE
21–34	A	Red
39–53	B	Yellow
48–68	C/D	Green
39–68	E	Brown

Also, wide-band aerials are available which cover all uhf television channels.

THE FREQUENCY SPECTRUM

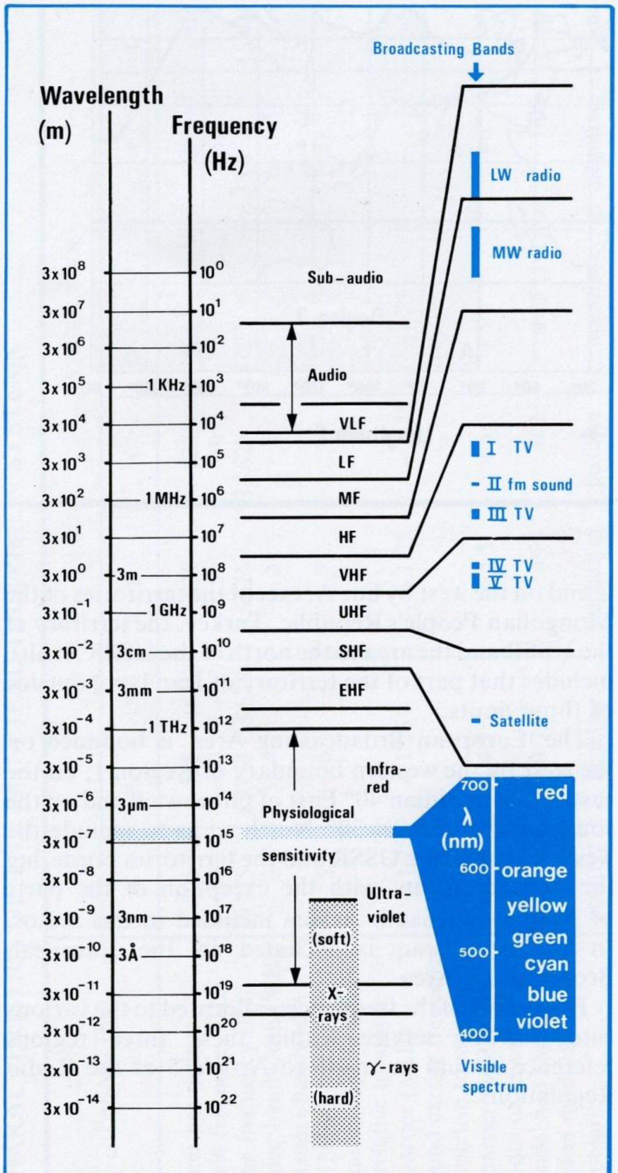


TABLE SHOWING CORRESPONDENCE BETWEEN CHANNEL NUMBERS AND ASSIGNED FREQUENCIES FOR THE 12 GHz SATELLITE BROADCASTING BAND

CHANNEL NO.	ASSIGNED FREQUENCY (MHz)	CHANNEL NO.	ASSIGNED FREQUENCY (MHz)
1	11 727·48	21	12 111·08
2	11 746·66	22	12 130·26
3	11 765·84	23	12 149·44
4	11 785·02	24	12 168·62
5	11 804·20	25	12 187·80
6	11 823·38	26	12 206·98
7	11 842·56	27	12 226·16
8	11 861·74	28	12 245·34
9	11 880·92	29	12 264·52
10	11 900·10	30	12 283·70
11	11 919·28	31	12 302·88
12	11 938·46	32	12 322·06
13	11 957·64	33	12 341·24
14	11 976·82	34	12 360·42
15	11 996·00	35	12 379·60
16	12 015·18	36	12 398·78
17	12 034·36	37	12 417·96
18	12 053·54	38	12 437·14
19	12 072·72	39	12 456·32
20	12 091·90	40	12 475·50

Note: UK channels are 4, 8, 12, 16 & 20. orbit position 31°W, polarisation left hand circular.

PROPOSED BROADCAST SATELLITE PARAMETERS FOR THE FREQUENCY BAND 11·7–12·5 GHz

Type of modulation	fm	
Number of lines	625	
Sound sub-carrier frequency	6 MHz	
Peak-peak deviation	13·3 MHz	
Peak deviation of sound sub-carrier	50 kHz	
Receiver equivalent rectangular noise bandwidth	27 MHz	
Angle of elevation	15°	40°
Luminance signal—unweighted noise for 99% of worst month	34 dB	33 dB
Sound signal to weighted noise ratio for 99% of worst month	51 dB	50 dB

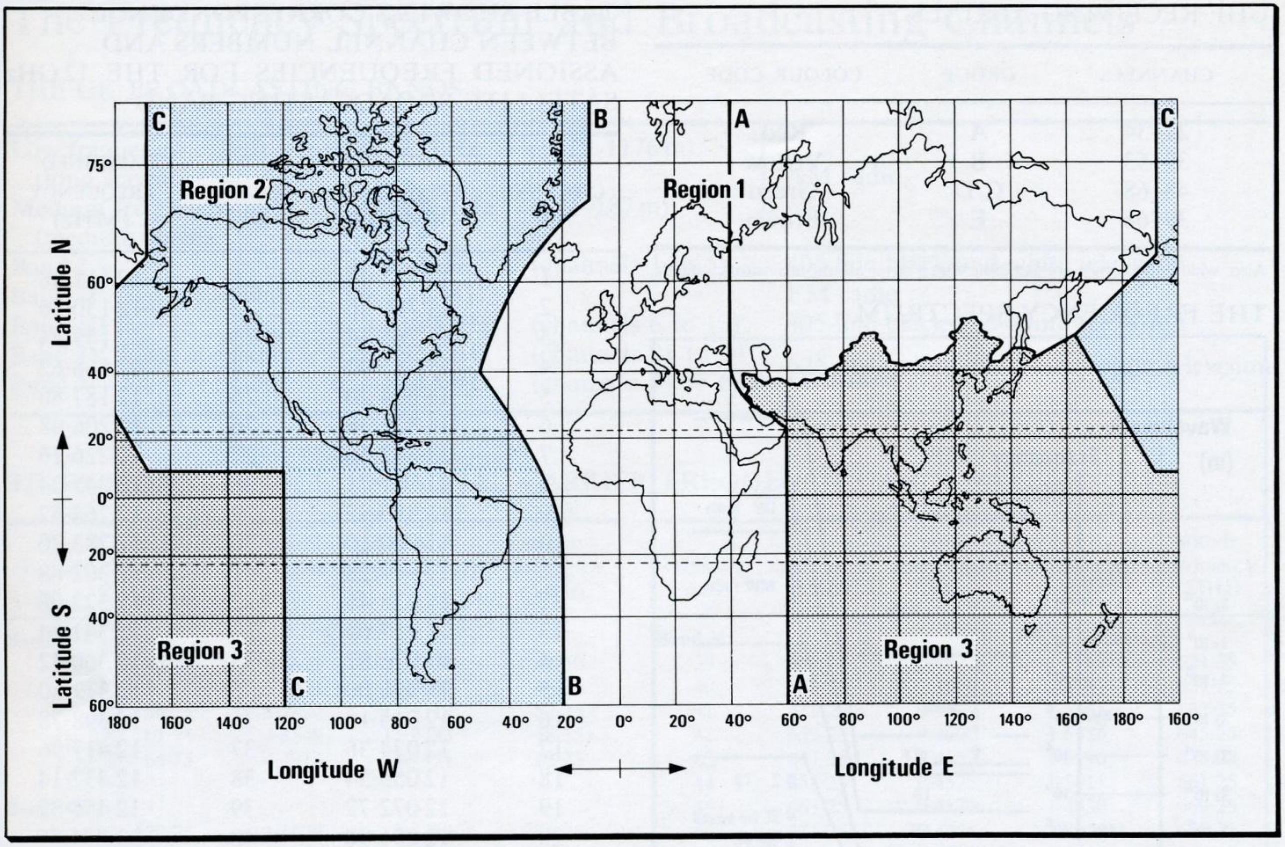


Chart of regions as defined in the Radio Regulations for the allocation of frequencies.

Frequency allocations in the range from 10 kHz to 275 GHz are contained in the Radio Regulations published by the General Secretariat of the International Telecommunication Union. These Regulations state that for the allocation of frequencies the world has been subdivided into three regions as shown in the figure.

Region 1 includes the area limited on the east by line A and on the west by line B, excluding any of the territory of Iran which lies between these limits. It also includes that part of the territory of Turkey and the Union of Soviet Socialist Republics lying outside of these limits, the territory of the Mongolian People's Republic, and the area to the north of the USSR which lies between lines A and C.

Region 2 includes the area limited on the east by line B and on the west by line C.

Region 3 includes the area limited on the east by line C and on the west by line A, except the territories of the Mongolian People's Republic, Turkey, the territory of the USSR and the area to the north of the USSR. It also includes that part of the territory of Iran lying outside of those limits.

The 'European Broadcasting Area' is bounded on the west by the western boundary of Region 1, on the east by the meridian 40° East of Greenwich and on the south by the parallel 30° North so as to include the western part of the USSR and the territories bordering the Mediterranean, with the exception of the parts of Arabia and Saudi Arabia included in this sector. In addition, Iraq is included in the European Broadcasting Area.

For details of the frequencies allocated to the various categories of service within these three regions reference should be made to Article 5 of the Radio Regulations.

CHARACTERISTICS OF THE PRINCIPAL TELEVISION SYSTEMS

PARAMETER	SYSTEM CODE								
	A	M (N)	B	C	G (H)	I	D K (K1)	L	E
Lines per picture	405	525 (625)	625	625	625	625	625	625	819
Field frequency (Hz)	50	60 (50)	50	50	50	50	50	50	50
Line frequency (Hz)	10 125	15 734 (15 625)	15 625	15 625	15 625	15 625	15 625	15 625	20 475
Video bandwidth (MHz)	3	4·2	5	5	5	5·5	6	6	10
Channel bandwidth (MHz)	5	6	7	7	8	8	8	8	14
Nearest edge of channel relative to vision carrier (MHz)	+1·25	−1·25	−1·25	−1·25	−1·25	−1·25	−1·25	−1·25	±2·83
Sound carrier frequency relative to vision carrier (MHz)	−3·5	+4·5	+5·5	+5·5	+5·5	+6	+6·5	+6·5	±11·15
Width of vestigial sideband (MHz)	0·75	0·75	0·75	0·75	0·75 (1·25)	1·25	0·75 (1·25)	1·25	2
Vision modulation polarity	positive	negative	negative	positive	negative	negative	negative	positive	positive
Sound modulation, pre-emphasis (μs)	am	fm ± 25 kHz 75	fm ± 50 kHz 50	am 50	fm ± 50 kHz 50	fm ± 50 kHz 50	fm ± 50 kHz 50	am	am

Notes

1. Figures quoted are nominal.
2. Data in brackets refers to system code shown in brackets at top of column.
3. For further information reference should be made to Report 624 (Rev. 76) of the Interim Meeting of CCIR Study Group 11, Geneva 1976.

Television Systems Used in Various Countries

The following is reproduced from Annex I of CCIR Report 624 (Rev. 76) Study Group 11.

COUNTRY	SYSTEM USED IN BANDS: I/III		SYSTEM USED IN BANDS: IV/V	
Algeria (Algerian Democratic and Popular Republic)	B, E/PAL	(13) (16)	G*, H*/PAL	(13) (16)
Germany (Federal Republic of)	B/PAL		G/PAL	
Netherlands Antilles	M		—	
Saudi Arabia (Kingdom of)	B		—	
Argentine Republic	N		N	
Australia	B/PAL	(22)	*/PAL	
Austria	B/PAL		G/PAL	(1)
Belgium	C, B/PAL	(17)	H/PAL	
Brazil (Federative Republic of)	M/PAL		M/PAL	
Bulgaria (People's Republic of)	D/SECAM		K/SECAM	
Burundi (Republic of)	K1*	(16)	K1*	(16)
Cameroon (United Republic of)	K1*	(15) (16)	K1*	(15) (16)
Canada	M/NTSC		M/NTSC	
Central African Republic	K1*	(16)	K1*	(16)
Cyprus (Republic of)	B		H*	(2) (18)
Colombia (Republic of)	M		M*	
Congo (People's Republic of the)	K1*	(16)	K1*	(16)
Korea (Republic of)	M		—	
Ivory Coast (Republic of the)	K1*	(16)	K1*	(16)
Cuba	M		M	
Dahomey (Republic of)	K1*	(16)	K1*	(16)
Denmark	B/PAL		G*	
Egypt (Arab Republic of)	B	(16)	G*, H*	(14) (16)
Group of Territories represented by the French Overseas Post and Telecommunication Agency	K1		—	
Spain	B		G	(2)
United States of America	M/NTSC		M/NTSC	
Ethiopia	B*	(16)	G*	(16)
Finland	B/PAL		G/PAL	
France	E		L/SECAM	
Gabon Republic	K1*	(16)	K1*	(16)
Ghana	B*, G*	(16)	G*	(16)
Greece	B*		G*	(3)
Guinea (Republic of)	K1*	(15) (16)	K1*	(15) (16)
Upper Volta (Republic of)	K1*	(16)	K1*	(16)
Hungarian People's Republic	D/SECAM		K/SECAM	
India (Republic of)	B		—	
Indonesia (Republic of)	B*		—	

COUNTRY	SYSTEM USED IN BANDS: I/III		IV/V	
Iran	B		G	
Ireland	A, I/PAL	(4)	I*	
Iceland		—	G*	(2) (5)
Israel (State of)	B		G	(6)
Italy	B/PAL		G/PAL	
Jamaica	N			—
Japan	M/NTSC		M/NTSC	
Jordan (Hashemite Kingdom of)	B		G*	
Kenya (Republic of)	B*	(16)	G*, I*	(16)
Kuwait (State of)	B		G*	(19)
Liberia (Republic of)	B*	(8) (16)	H*	(8) (16)
Libyan Arab Republic	B*	(16)	G*	(16)
Luxembourg	C		L*	(2)
Malaysia	B		G*	
Malawi	B*	(10) (16)	G*	(10) (16)
Malagasy Republic	K1*	(16)	K1*	(16)
Mali (Republic of)	K1*	(16)	K1*	(16)
Morocco (Kingdom of)	B		H*	
Mauritius	B			—
Mauritania (Islamic Republic of)	K1*	(16)	K1*	(16)
Mexico	M			—
Monaco	E		L*	
Niger (Republic of the)	K1*	(16)	K1*	(16)
Nigeria (Federal Republic of)	B	(16)	I*	(16)
Norway	B/PAL		G*	(3)
New Zealand	B/PAL			—
Uganda (Republic of)	B	(9) (16)	G*	(9) (16)
Pakistan	B			—
Panama (Republic of)	M			—
Netherlands (Kingdom of the)	B/PAL		G/PAL	(21)
Peru	M		M	
Poland (Peoples's Republic of)	D/SECAM		K/SECAM	
Portugal	B		G	
Portuguese Oversea Provinces	I*	(16)	I*	(16)
German Democratic Republic	B/SECAM		G/SECAM	
Rhodesia	B	(10)	G*	(10)
Roumania (Socialist Republic of)	D		K*	(2)
United Kingdom of Great Britain and Northern Ireland	A		I/PAL	

COUNTRY	SYSTEM USED IN BANDS:			
	I/III		IV/V	
Rwanda (Republic of)	K1*	(16)	K1*	(16)
Senegal (Republic of the)	K1*	(16)	K1*	(16)
Sierra Leone	B	(11) (16)	G*	(16)
Singapore (Republic of)	B		G*	(20)
Somali Democratic Republic	B*	(16)	G*	(16)
Sri Lanka (Ceylon) (Republic of)	B		—	
South Africa (Republic of)	I*	(16)	I*	(16)
Sweden	B/PAL		G/PAL	
Switzerland (Confederation of)	B/PAL		G/PAL	(7)
Surinam	M		—	
Tanzania (United Republic of)	B*, I*	(12) (16)	I*	(12) (16)
Chad (Republic of the)	K1*	(16)	K1*	(16)
Czechoslovak Socialist Republic	D/SECAM		K/SECAM	
Oversea Territories for the international relations of which the Government of the United Kingdom of Great Britain and Northern Ireland are responsible	B*, I*	(16)	I*	(16)
Oversea Territories of the United Kingdom in the European Broadcasting Area	—		H*	(2)
Togolese Republic	K1*	(16)	K1*	(16)
Turkey	B		G*	
Union of Soviet Socialist Republics	D/SECAM		K/SECAM	
Uruguay (Oriental Republic of)	N		—	
Venezuela (Republic of)	M		—	
Yugoslavia (Socialist Federal Republic of)	B/PAL		G/PAL	
Zaire (Republic of)	K1*	(15) (16)	K1*	(15) (16)
Zambia (Republic of)	B*	(10) (16)	G*	(10) (16)

* planned (whether the standard is indicated or not);
— not yet planned, or no information received;
/ the abbreviation following the stroke indicates the colour transmission system in use (NTSC, PAL, or SECAM);
(Figures in brackets refer to the following notes.)

Notes

1. Austria reserves the right to the possible use of additional frequency-modulated sound carriers, in the band between 5·75 and 6·75 MHz, in relation to the picture carrier.
2. The Indications and Notes are based on indications and notes given in Chapter 2 of the 'Technical data used by the European VHF/UHF Broadcasting Conference'.
3. No definite decision has been taken about the width of the residual sideband, but this country is willing to accept the assumption that for planning purposes the residual sideband will be 0·75 MHz wide.
4. System I will be used at all stations. In addition, during a transition period, transmissions on system A will be made from the Dublin and Sligo stations.
5. This country does not at present intend to use Bands IV and V, but accepts the parameters given in the table under 'Standard G' as television standard in Bands IV and V.
6. No final decision has been taken about the width of the residual sideband, but for planning purposes this country is willing to accept the assumption of a residual sideband 1·25 MHz wide.
7. The Swiss Administration is planning to use additional frequency-modulated sound carriers, in the frequency interval between the spacings of 5·5 and 6·5 MHz in relation to the picture carrier, at levels lower than or equal to the normal level of the sound carrier, for additional sound-tracks or for sound broadcasting.
8. Liberia accepted for planning purposes Standard B or H but reserves the right to adopt Standard M.
9. Uganda is already committed to Standard B in band III. Standard G is planned for bands IV and V although further consideration will be given to other standards when bands IV and V stations are to be commissioned.
10. Indications for Malawi, Rhodesia and Zambia are based on indications for Rhodesia and Nyasaland (Federation of) given in the Final Acts of the African VHF/UHF Broadcasting Conference, Geneva, 1963. Standard B is now in use in band I; no final decision is taken regarding systems to be used in bands III, IV and V.
11. Sierra Leone now uses Standard B but reserves the right to use any other standard compatible with the Plan.
12. Tanzania, the indications are based on indications for Tanganyika and

Zanzibar given in the Final Acts of the African VHF/UHF Broadcasting Conference, Geneva, 1963. It is intended to use Standard B in bands I and III. Although Standard I is planned for bands IV and V, further consideration will be given to the use of Standards G and H.

13. Algeria reserves the right to change later.

14. The Arab Republic of Egypt is now studying the adoption of either Standard G or H for bands IV and V.

15. In Cameroon, Zaire and Guinea, planning has been based on Standard K1, but they reserve the right to use any other standard compatible with the Plan when they introduce television.

16. The Indications and Notes 10 to 17 are based on indications and notes given in the Final Acts of the VHF/UHF African Broadcasting Conference, Geneva, 1963.

17. Belgium will use Standard C in bands I and III until April 1977, after which Standard B will be used.

18. Cyprus is already committed to the use of Standard B in band III. Standard H is envisaged for use in bands IV and V, although further consideration will be given to the possible use of other standards when stations operating in bands IV and V are to be commissioned.

19. In Kuwait, if the services are called upon to broadcast in a second language, the frequencies between 5·5 MHz and 6·5 MHz could be used to provide an additional frequency-modulation sub-carrier.

20. Singapore reserves the right to use additional frequency-modulation sound channels in the band between 5·5 and 6·5 MHz in relation to the picture carrier, for additional sound channels for sound broadcasting.

21. Some existing transmitters operate with a residual sideband up to 1·25 MHz. For the future, only transmitters with a residual sideband of 0·75 MHz are foreseen.

22. Australia uses nominal modulation levels as specified for system I.

Characteristics of 625-Line Systems for International Exchange of Programmes

CCIR Recommendation 472-1 (Study Group 11) dealing with video-frequency characteristics for the international exchange of programmes between countries that have adopted 625-line colour or monochrome systems is reproduced as follows.

1. The video characteristics recommended for the international exchange of programmes between countries that have adopted 625-line colour or monochrome television systems are given below. In particular, countries that use Systems B, C, D, G, H, I, K, K1 and L will facilitate programme interchange by adopting these characteristics.

Note 1.—The details concerning the line-blanking and field-blanking intervals are listed in the same order and are designated by the same symbols as in Report 624 (Rev. 76).

Note 2.—This Recommendation is not intended to apply to Standard N.

2. General characteristics

2.1 Number of lines per picture:	625
2.2 Line frequency and tolerance f_H (Hz)(1)	
—monochrome transmissions:	$15\,625 \pm 0{\cdot}02\,\%$
—colour transmissions:	$15\,625 \pm 0{\cdot}0001\,\%$
2.3 Field frequency f_v (Hz):	$(2/625) f_H$
2.4 Picture-frame frequency f_p (Hz):	$f_H/625$
2.5 Gamma of picture signal:	approx. 0·4
2.6 Nominal video bandwidth (MHz):	5, or 5·5, or 6 (2)
2.7 Nominal difference between black level and blanking level (as a percentage of the luminance amplitude):	0^{+5}_{-0}

3. Details of line-blanking interval(3)

(H) Nominal duration of a line:	$H = 64\,\mu s$
(a) Line-blanking interval:	$12 \pm 0{\cdot}3\,\mu s$
(b) Interval between datum (O_H) and back edge of line-blanking signal (average calculated value for information):	$10{\cdot}5\,\mu s$
(c) Front porch:	$1{\cdot}5 \pm 0{\cdot}3\,\mu s$
(d) Synchronising pulse:	$4{\cdot}7 \pm 0{\cdot}2\,\mu s$
(e) Build-up time (10–90 %) of line-blanking edges:	$0{\cdot}3 \pm 0{\cdot}1\,\mu s$
(f) Build-up time (10–90 %) of line-synchronising pulses:	$0{\cdot}2 \pm 0{\cdot}1\,\mu s$

4. Details of the field-blanking interval

(j) Field-blanking period:	$25H + a$(4)
(k) Build-up time (10–90 %) of field-blanking edges as in (e):	$0{\cdot}3 \pm 0{\cdot}1\,\mu s$
(l) Duration of first equalising pulse sequence:	$2{\cdot}5H$, or $3H$(5)
(m) Duration of field-synchronising pulse sequence:	$2{\cdot}5H$, or $3H$(5)
(n) Duration of second equalising pulse sequence:	$2{\cdot}5H$, or $3H$(5)
(p) Duration of equalising pulse (one half the value given in (d)):	$2{\cdot}35 \pm 0{\cdot}1\,\mu s$
(q) Duration of field-synchronising pulse (average calculated value for information):	$27{\cdot}3\,\mu s$
(r) Interval between field-synchronising pulses as in (d):	$4{\cdot}7 \pm 0{\cdot}2\,\mu s$
(s) Build-up time (10–90 %) of field-synchronising pulses as in (f):	$0{\cdot}2 \pm 0{\cdot}1\,\mu s$

References

(1) When the reference of synchronism is being changed, the tolerance for colour transmissions may be increased to $\pm 0{\cdot}001\,\%$ (see Report 624, Rev. 76). Attention is drawn to the desirability of adding to these characteristics a value for the maximum rate of change of line frequency.

(2) The attention of Study Groups 4 and 9 and the CMTT is drawn to the desirability of subsequently standardising tolerances for corresponding

transmission characteristics applicable to all 625-line systems. For international routine measurements, it is suggested that the test signals be based on a single reference frequency which could be 5 MHz, particularly by countries using systems with nominal video bandwidth of 6 MHz. For example, this suggestion is not contrary to the use of a frequency close to 6 MHz in a multiburst test signal.

([3]) The nominal value of the picture-synchronising signal ratio is 7/3. For details of permitted tolerances in long-distance transmissions, see Recommendations 421-3, §2·3 and 451-2, §3·3.

([4]) In the blanking interval, lines 16, 17, 18, 19, 20, 21, and 329, 331, 332, 333 and 334 are reserved for the reception of any special signals.

([5]) These values may be subject to revision in the case where a single equalising pulse system might be adopted (see Doc. XI/115 (United Kingdom) 1963–1966 and Report 626).

Preferred Viewing Conditions

CCIR Recommendation 500 (Rev. 76), Annex Section 2.4, states that the preferred viewing conditions are affected by the field frequency of the television system, and that the conditions for systems with 50 and 60 fields per second are as shown in the following Table.

CONDITION	FIELD FREQUENCY	50 FIELDS PER SECOND	60 FIELDS PER SECOND
a	Ratio of viewing distance to picture height	6 (1)	4 to 6
b	Peak luminance on the screen (cd/m^2)	70 ± 10 (2)	70 ± 10
c	Ratio of luminance of inactive tube screen (beams cut off) to peak luminance	$\leqslant 0{\cdot}02$	$\leqslant 0{\cdot}02$
d	Ratio of the luminance of the screen when displaying only black level in a completely dark room, to that corresponding to peak white	approximately 0·01	
e	Ratio of luminance of background behind picture monitor to peak luminance of picture	approximately 0·1(3)	approximately 0·15
f	Other room illumination	low (4)	low
g	Chromaticity of background	white (5)	D_{65}
h	Ratio of solid angle subtended by that part of the background which satisfies this specification, to that subtended by the picture	$\geqslant 9$	

(1) Normally 6; if a different ratio is used, this should be stated.
(2) Normally $(70 \pm 10)\, cd/m^2$, or (220 ± 30) asb (6), but certain tests may require luminances outside the tolerances, for example, because of flicker, defocusing, etc.
(3) If the ratio is greater than 0·1, the chromaticity has to be nearer to Illuminant D_{65}(7).
(4) The specification is loosely phrased here, since the precise value is not critical, provided it does not conflict with condition *c*.
(5) Not very critical. Any white in the region between standardised illuminants A and D_{65}. See, however, Note (3).
(6) 1 apostilb (asb) = $1/\pi$ candela per square metre (cd/m^2).
(7) Illuminants standardised by the International Commission on Illumination (CIE); see International Electrotechnical Vocabulary, Group 45, No. 45-15-145.

Broadcasting Aerials

1. UHF TELEVISION TRANSMITTING AERIALS

Definitions of Terms Used

Aperture. The vertical aperture, A, of a transmitting aerial comprising n tiers of radiating elements (e.g. dipoles, slots, etc.) is defined as $n \times$ the element spacing in wavelengths.

Maximum Gain. With respect to an isotropic radiator the gain of a long uniformly illuminated aperture is given by $G_0 = 2A$. This expression is valid for aerials of large vertical aperture (i.e. greater than 8λ) provided that the inter-tier spacing is less than λ and the aerial pattern is omnidirectional in the horizontal plane. Most aerials for uhf main stations satisfy this requirement.

It is normal to define gain with respect to a half-wave dipole, which has a gain 1·64 times greater than an isotrope. Hence, the aerial gain relative to a dipole is

$$G = \frac{2A}{1{\cdot}64} = 1{\cdot}22A.$$

Since, in practice, the horizontal radiation patterns of some aerials are directional, the maximum gain is given by the product of G and a horizontal gain factor.

Vertical Radiation Pattern (VRP). The radiated field from a transmitting aerial varies inversely as the range. In order to provide an approximately uniform field over the service area it is necessary to shape the vertical radiation pattern such that it becomes proportional to cosec θ, where θ is the declination from the horizontal.

A simple, vertical linear array of radiating elements fed with equal currents which lag progressively by a phase angle, ϕ, between each element will have a vertical radiation pattern, vrp, given by

$$F(\theta) = \frac{\sin(\pi n d \sin\theta + \phi/2)}{n \sin(\pi d \sin\theta + \phi/2)},$$

where n = the number of elements
and d = the spacing between elements in wavelengths.

Figure 1 shows the pattern produced by $F(\theta)$. From this it will be seen that there is a series of sharp nulls at intervals of $\sin^{-1}(1/nd)$ which, for a practical transmitting aerial, must be at least partially filled.

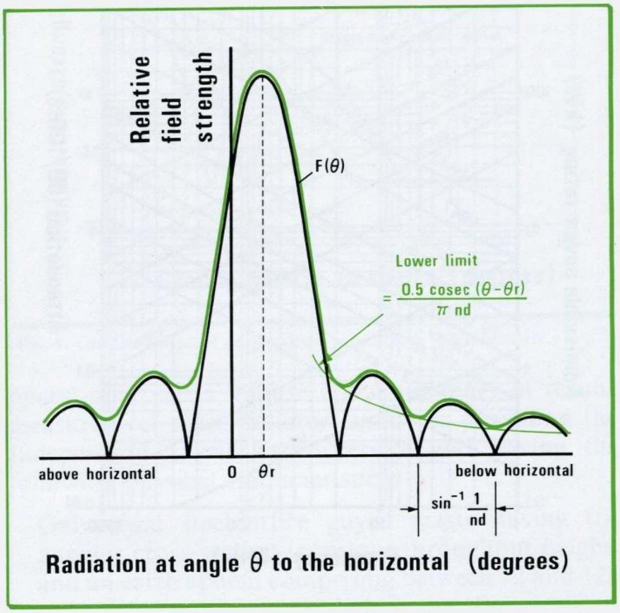


Fig. 1. The vertical radiation pattern (vrp) of a large-aperture linear array.

This is achieved by modifying the vrp to become $m \operatorname{cosec}(\theta - \theta_r)/\pi n d$, where θ_r is a small angle through which the main beam is normally tilted below the horizontal. The usual lower limit of m is 0·5.

The vrp is dependent on the amplitudes and phases of the currents radiated by the elements and the element spacing, and it is practicable to control these parameters to achieve the required pattern.

Null Fill Loss. The nulls that would occur in an array fed with equal co-phased currents as described above are filled in compliance with the vrp specification. The change in current distribution required to achieve this reduces the available gain. The ratio between the maximum field from the aerial and the maximum field that would exist were the same total power to be uniformly distributed gives the null fill loss. Typically this is between 1 and 1·5 dB.

Effective Gain. In determining the effective gain of a transmitting aerial it is necessary to take account of the dissipative losses in feeders and combining filters, together with the null fill loss. Feeder attenuation for many of the more common sizes of feeder in regular use can be determined from Fig. 2.

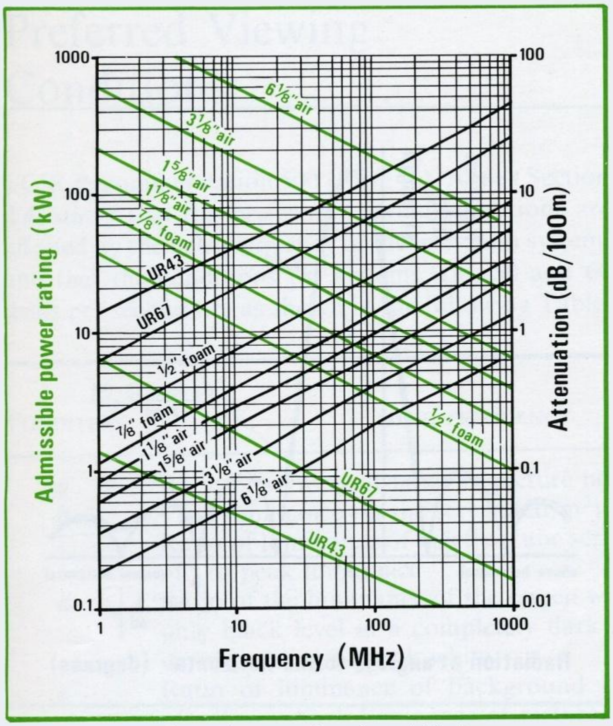


Fig. 2. The attenuation and power rating of coaxial feeders.

Impedance. To avoid delayed images being radiated the input impedance of a transmitting aerial must closely match the characteristic impedance of the feeder connecting it to the transmitter. Figure 3 gives alternative permitted values. Using the new 5-point impairment scale introduced on 1st July 1977 by

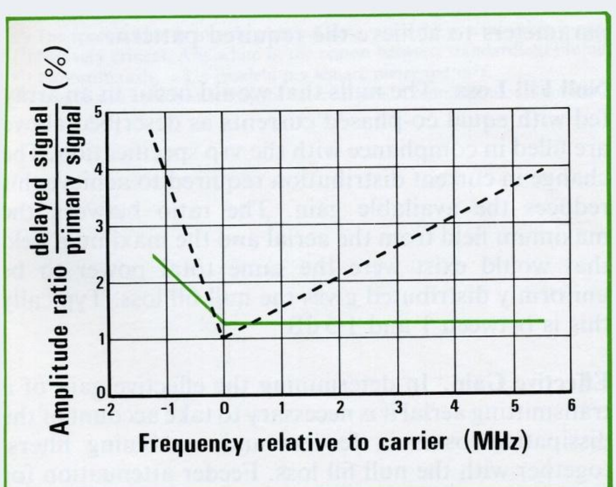


Fig. 3. Delayed image specification for uhf transmitting aerials. The two characteristics shown here provide equal subjective performance.

the IBA for assessing technical quality, the mid-opinion subjective assessment for maximum permissible delayed-image distortion resulting from the specification shown in Fig. 3 is severity grade 4·5, i.e. midway between 'imperceptible' and 'perceptible but not annoying'.

The aerial impedance may be relaxed by an amount equivalent to the loss which the delayed-image signal suffers in making two traversals of the feeder and combining filters, plus the output return loss of the transmitter. For short delays (less than 0·3 μs) a further 6 dB relaxation is permitted.

Effective Height of Transmitting Aerial

For elevated transmitting aerials at vhf/uhf, the effective height is defined as the centre of the transmitting aerial above the mean level of the ground between 3 and 15 km from the transmitter in the direction in which it is desired to determine the field strength.

2. UHF TELEVISION RECEIVING AERIALS FOR RE-BROADCAST USE

The re-broadcast receiving (rbr) aerial system must satisfy two criteria.

i Adequate signals must be available at the receiver/transposer input. Figure 4 indicates the aerial complement needed to satisfy the present standards in respect of terminated voltage and signal/noise performance at uhf relay stations. The information contained in this diagram is based on there being

a at transposer stations having aerial systems without amplifiers and working either to the joint IBA/BBC Standard P (serving populations in excess of 2000) or the Standard Q (serving populations less than 2000), a signal input of 2 mV or 1·5 mV respectively,

b an in-station signal/noise performance of 42 dB and 39 dB at transposer stations having aerial systems with amplifiers and respectively working to the Standards P and Q as above, and

c a feeder and channel-separating filter loss of 4 dB.

ii Unwanted interference from co-channel and/or adjacent channel sources and multipath signals must be reduced to acceptable levels.

Figure 5 gives the discrimination templets used for rbr aerials. Where less directivity can be tolerated, either single or double arrays of log periodic aerials can be employed. The templets for such combinations are given in Fig. 6.

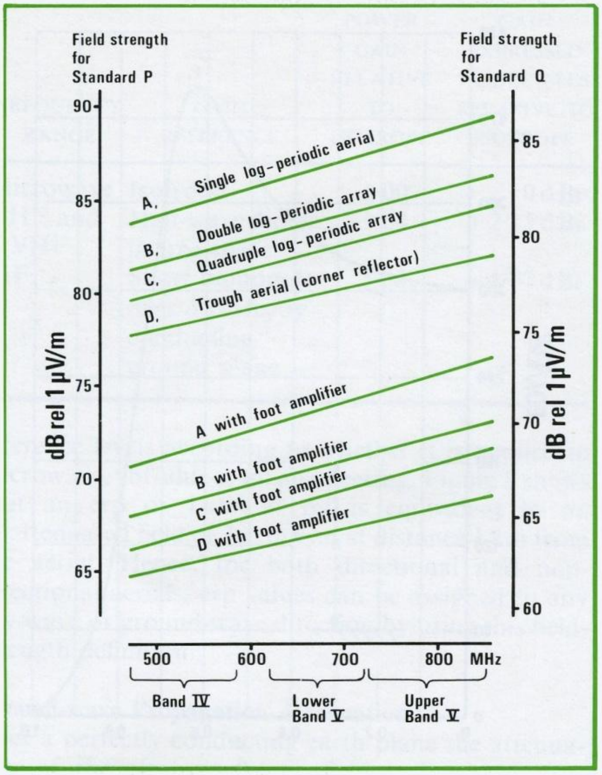


Fig. 4. Aerial complement planning chart for re-broadcast receivers.

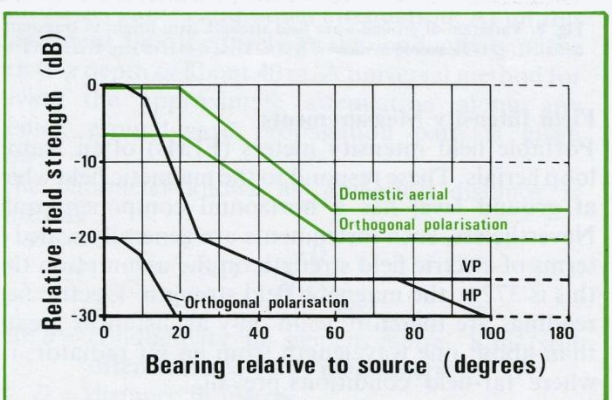


Fig. 5. Discrimination of re-broadcast aerials with high directivity. VP = vertical polarisation, HP = horizontal polarisation.

3. MEDIUM-FREQUENCY MAST RADIATORS

Impedance of Base-fed Mast Radiators

Text-book charts showing the theoretical base impedance of cylindrical radiators generally give values significantly different from those measured on

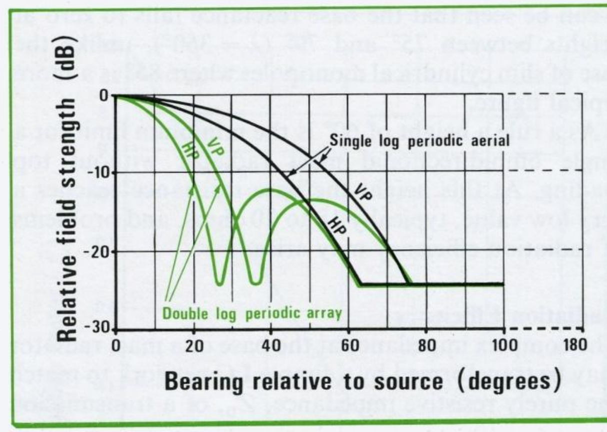


Fig. 6. Discrimination of re-broadcast aerials with low directivity.

operational masts. Figure 7 is a summary of results measured on mast radiators used for providing the Independent Local Radio service and having the following physical characteristics:

Galvanised steel-lattice guyed masts having triangular cross-section (constant throughout height) and an earth system comprising between 72 and 120 radial copper wires extending to a radius approximately equivalent to the height of the mast in each case.

Height range = 45 to 70 m above base insulator

Face widths = 380 to 640 mm
Height/width ratios = 80 to 160.

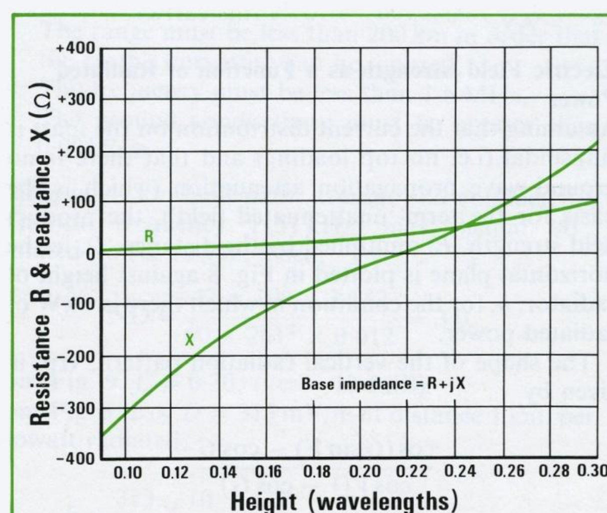


Fig. 7. Measured base-impedance characteristics of mast radiators without top loading.

It can be seen that the base reactance falls to zero at heights between 75° and 79° ($\lambda = 360°$), unlike the case of slim cylindrical monopoles where 85° is a more typical figure.

As a rule a height of 60° is the minimum limit for a single omnidirectional mast radiator without top loading. At this height the base resistance reaches a very low value, typically 18 to 20 ohms, and problems of radiation efficiency may arise.

Radiation Efficiency

The complex impedance at the base of a mast radiator may be transformed by a simple LC network to match the purely resistive impedance, Z_0, of a transmission line, e.g. a 50 ohm coaxial feeder. The power, P, fed to the mast base is then $I_L^2 Z_0$ watts, where I_L is the line current.

Apart from a slight loss in the matching network, this power is dissipated in the resistive component, R, of the base impedance of the mast. But the measured value of R contains not only the radiation resistance of the mast but also the loss resistance of the radial earth system, typically 5 ohms for a 72-wire system of radius $0{\cdot}2\lambda$.

Example: 60° mast; measured base impedance $R + jX = 18 - j100$ ohms.

If input power, $P = 1\,kW$, the base current, $I_b = \sqrt{P/R} = 7{\cdot}45$ A, the radiated power for 5 ohms earth loss $= I_b^2(18 - 5) = 722$ W, and the base voltage $= I_b\sqrt{18^2 + 100^2} = 757$ V rms carrier.

Electric Field Strength as a Function of Radiated Power

Assuming that the current distribution on the mast is sinusoidal (i.e. no top loading) and that there is no ground-wave propagation attenuation (which is the basis for the term 'unattenuated field'), the product field strength, E, multiplied by the distance, D, in the horizontal plane is plotted in Fig. 8 against height of radiator, h, for the condition in which there is 1 kW of radiated power.

The shape of the vertical radiation pattern, vrp, is given by

$$\frac{\cos(G \sin V) - \cos G}{\cos V(1 - \cos G)},$$

where V = angle above horizontal,
G = height of radiator in electrical degrees.

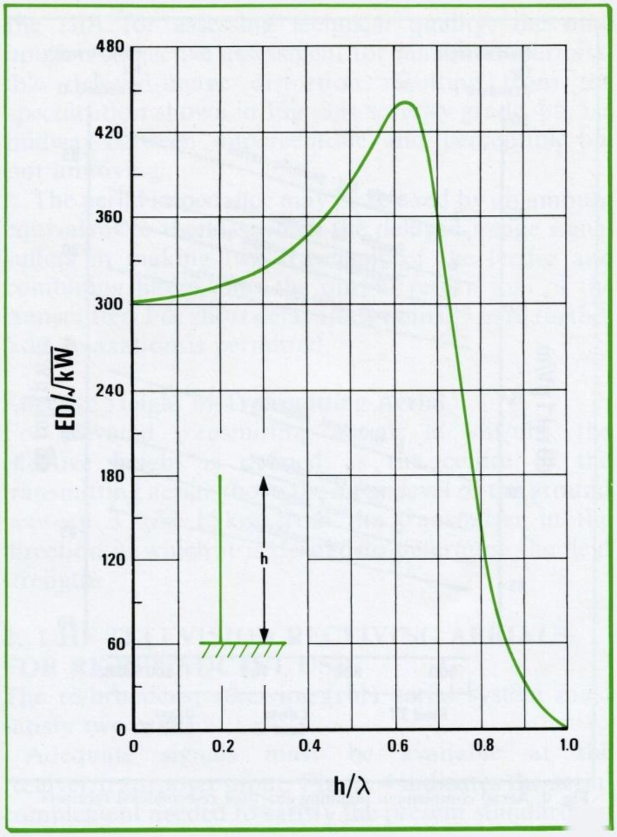


Fig. 8. Variation of ground-wave field strength with height of transn aerial. (If D is measured in metres, E is in V/m; if D is in km, E is in mV

Field Intensity Measurements

Portable field intensity meters (FIMs) often feature loop aerials. These respond to the magnetic field which at ground level has a horizontal component only. Nevertheless, such instruments are generally scaled in terms of electric field strength on the assumption that this is 377 × the magnetic field strength. Electric field readings are therefore valid only at distances greater than about one wavelength from an mf radiator, i.e. where 'far-field' conditions prevail.

Aerial Gain and Effective Radiated Power

It is of interest to compare the mf gain reference with the isotropic reference used in microwave link work and with the half-wave dipole reference used in vhf and uhf engineering.

Furthermore, effective radiated power (erp) in a given direction is the product of 'transmitter power' and 'aerial gain in that direction expressed as a power ratio', and therefore, being based on gain, has different

FREQUENCY RANGE	GAIN REFERENCE	POWER GAIN RELATIVE TO ISOTROPE	GAIN EXPRESSED IN DECIBELS RELATIVE TO ISOTROPE
Microwave	Isotrope	1·00	0 dBi
UHF and VHF	Half-wave dipole in free space	1·64	+2·15 dBi
MF	Short monopole over a perfectly conducting ground plane	3·00	+4·77 dBi

reference levels according to whether it is applied to microwave, vhf/uhf, or mf engineering. Figure 8 shows that an erp of 1 kW at mf is equivalent to an unattenuated field of 300 mV/m at distance 1 km from the aerial. Hence, for both directional and non-directional aerials, erp values can be assigned to any sky-wave or ground-wave direction by using this field-strength definition.

Ground-wave Propagation Attenuation

Over a perfectly conducting earth plane the attenuation of the electromagnetic field is inversely proportional to the range, but in practice soil of a finite conductivity causes additional attenuation. At mf this is dependent almost entirely on the conductivity of the earth to a depth of about 40 m. A universal method for deriving the approximate attenuation along any specified ground-wave propagation path is given below.

The parameter known as 'numerical distance' is defined as

$$\mathrm{ND} = \frac{\pi D}{60\lambda^2\sigma},$$

where σ = conductivity in siemens/metre, S/m (still often referred to as mhos/metre)

D = distance in metres,

and λ = wavelength in metres.

Then, from Fig. 9, the attenuation factor, f_a, which represents the additional attenuation due to finite ground conductivity, can be derived. Typical ground conductivities are as follows:

Very dry soil	(poor)	0·001 S/m
Damp soil, or fresh water	(good)	0·01 S/m
Sea water	(excellent)	4·0 S/m.

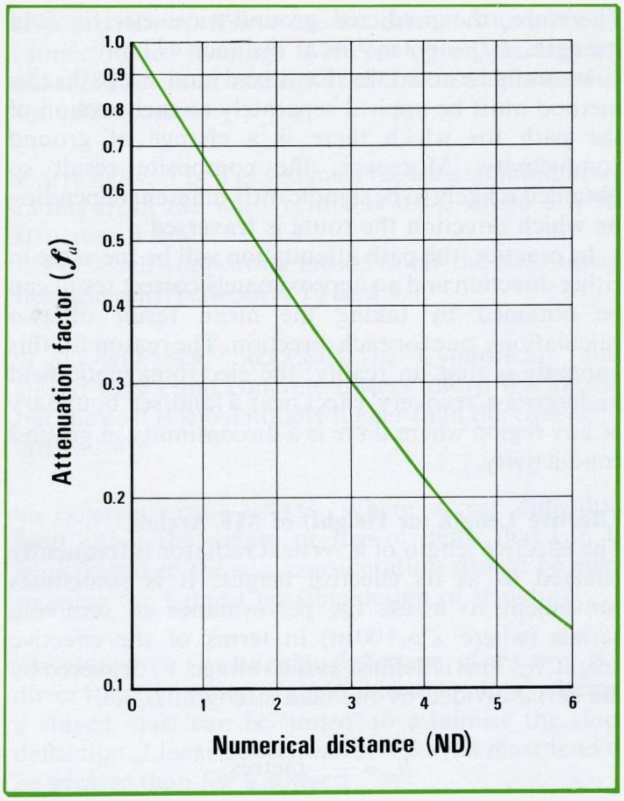


Fig. 9. Variation of attenuation factor, f_a with numerical distance, ND.

The validity of this method is restricted to cases where the following conditions apply:

i The range must be less than 200 km in order that the earth's curvature can be ignored,
ii The frequency must be less than 1·6 MHz,
iii The ground conductivity must be greater than 0·001 S/m.

Example: 47 km land path, average soil conductivity 12 mS/m, frequency 1151 kHz, mast height 90°, radiated power 10 kW; Then,

$$\mathrm{ND} = \frac{47 \times 10^3 \times 3{\cdot}142}{60 \times 261^2 \times 0{\cdot}012} = 3{\cdot}0,$$

from Fig. 9, $f_a = 0{\cdot}30$, (i.e. $-10{\cdot}5$ dB),
from Fig. 8, $E \times D = 313$ mV/m at distance 1 km, per kilowatt radiated,

$$\therefore E = \frac{313\sqrt{10}}{47}$$

$$= 21 \;\; \mathrm{mV/m} \text{ unattenuated field at 47 km.}$$

Therefore, the predicted ground-wave electric field strength, $Ef_a = 6{\cdot}3\,\text{mV/m}$ at distance 47 km.

It should be noted that for mixed land/sea paths this method must be applied separately to each section of the path for which there is a change of ground conductivity. Moreover, the composite result so obtained is likely to be significantly different depending on which direction the route is traversed.

In practice, the path attenuation will be the same in either direction and an approximately correct result can be obtained by taking the mean result of two calculations, one for each direction. The reason for this anomaly is that, in reality, the electromagnetic field undergoes a 'recovery' effect near a land/sea boundary or any region where there is a discontinuity in ground conductivity.

Effective Length (or Height) of MF Aerials

The effective length of a vertical radiator is frequently referred to as its effective height. It is sometimes convenient to assess the performance of receiving aerials (where $\lambda > 100\,\text{m}$) in terms of the effective height, h_e. This is defined as the voltage, V, delivered by the aerial divided by the field strength, E, i.e.

$$h_e = \frac{V}{E} \quad \text{metres.}$$

Directional MF Transmitting Aerials

Directional radiation patterns can be obtained from arrays of two or more mf radiators in which the individual rf current amplitudes and phases are adjusted to yield desired radiation characteristics. The radiators are usually guyed masts or self-supporting towers, but in some cases are wires supported from other structures. Arrays may be in the form of a single line of radiators, giving either 'broadside' or 'endfire' beams of radiation, or they may be constructed in the form of a parallelogram.

In some instances, all the radiators in an array may be actively fed from the transmitter through power-dividing and phase-shifting networks; in others, one or more radiators may be excited merely by mutual coupling from other radiators and are connected to earth either directly or through tuning reactances. As a rule, the effects of mutual coupling are very significant in directional arrays. Thus the *operating* impedances of actively fed radiators will differ from one another, even if the radiators themselves are all identical, and will generally be quite different from the impedance of an isolated radiator such as was dealt with above. Further information on the Authority's directional mf transmitting aerials is contained in *IBA Technical Review 5*. For information on the dual-frequency directional array used for providing the two ILR services in the London area, reference should be made to *International Broadcasting Convention 1976, IEE Conference Publication Number 145, pp. 215–218*.

4. VHF RADIO TRANSMITTING AERIALS

Directional and omnidirectional vhf radio aerials are similar in many respects to their uhf television counterparts. For ILR fm transmissions radiators are arranged in vertical stacks ranging from two to six wavelengths high. Impedance specifications are less stringent than those for uhf television and consequently aerials can be made to operate over a substantial portion of Band II. However, as was mentioned for television aerials, delayed signals can also cause degradation of fm transmissions, therefore the reflection coefficient is usually limited to 10 per cent over the operating channels.

Whereas the national services of the BBC use horizontal polarisation, the ILR services are generally transmitted with both horizontal and vertical components simultaneously. In this way, not only is a service provided for listeners having horizontally polarised rooftop receiving aerials, but there is also a considerable improvement in reception for motorists using vertical whip aerials.

Normally, the two components of polarisation are transmitted with roughly equal erp. Depending on their phase relationship one to the other, the resultant radiated field may have a fixed, slanted, linear polarisation, or it may rotate at a rate synchronous with the carrier frequency to form a circularly polarised field. This is analagous to the generation of Lissajous figures. Although some use is made of horizontal and slant polarisations, the majority of ILR vhf stations employ circular polarisation. The transmitting aerials usually consist of separate linear elements such as dipoles, loops or yagis arranged in pairs, each pair comprising a horizontal and vertical element fed in quadrature to launch a circularly polarised wave. In some instances, helical aerial elements are used to generate circular polarisation directly. The degree of circularity is not critical and a tolerance of ± 3 dB is allowed on the equality of the vertical and horizontal field components.

It is not necessary to employ a circularly polarised aerial to receive such transmissions. An ordinary linear aerial mounted horizontally or vertically or at any slant angle in the plane of the wavefront will extract roughly

half of the available energy from the field and therefore be only some 3 dB less efficient than an equivalent circularly polarised aerial. For further information on vhf aerials and circular polarisation, see *IBA Technical Review 5*.

5. AERIAL SUPPORT STRUCTURES

Aerial support structures can be divided into two main sub-divisions—self-supporting towers and guyed masts. The choice of structure for any given application depends primarily on the capital cost, which in turn is governed by a number of other factors including the cost of maintenance and the site conditions available. It follows that for any given set of circumstances there is one design of structure which will be the most economical, and while it is not possible to give specific weightings to each of these factors the following guidelines generally apply.

i HEIGHT. The weight, and therefore the cost, of a free-standing tower varies approximately as the square of its height. Generally, for structures taller than 100 m a guyed mast is more economical, but in town centres and other restricted areas a tower is often the only practical solution.

ii AERIAL LOADING. This develops mainly from the effective wind area of the aerials together with their associated feeders, and the deadweight of each. Structure cost is usually proportional to the effective area of the aerials for any given height.

Various shapes have different 'shape factors' which are determined from wind tunnel tests. These can then be applied to the full projected area to give the effective area.

iii WIND LOADING. Dynamic pressure exerted by the wind on the structure and aerials is proportional to the square of the windspeed, which in turn is a function of the height of the point of application above ground level. Studies in the UK postulate that

$$V_h = V_{10}\left[\frac{h}{10}\right]^{\alpha},$$

where V_h is the windspeed at height h metres,
V_{10} is the basic windspeed at 10 metres above ground level
and α is an exponent calculated from topographical factors, as explained in British Standards Institution publication CP3, Chapter V, Part 2: 1972.

iv ICE LOADING. There are no current standards for estimating ice loadings. Meteorological records and observations must be consulted and assumption made for each location.

v SITE AREA. For a guyed mast the usual minimum site radius from the mast centre is $0{\cdot}8h$, where h is the structure height.

For a self-supporting lattice tower the base square lies generally between $h/10$ and $h/7$.

vi ALL-WEATHER ACCESSIBILITY. Cylindrical steel stayed masts and concrete towers afford this facility but the cost is substantially higher than the equivalent lattice form.

vii CONSTRUCTION ACCESS. Where access difficulties limit either the weight or size of items that can be transported to the site, consideration should be given to using the lightest possible design of structure.

viii RIGIDITY. The angular deflection of a tower is a direct function of its height and total loading, whereas a stayed mast can be 'tuned' to minimise the slope deflection. Linear deflections of a stayed mast tend to be greater than for a tower.

ix GROUND CONDITIONS. Where subsidence is a problem a guyed mast offers more scope for adjustment and can overcome differential settlement which would be a problem for a self-supporting tower.

x AERODYNAMIC BEHAVIOUR. Some structures are sensitive to wind-excited oscillations due to vortex shedding, or to induced vibrations ocurring in stays or associated fittings. Where this is likely, methods of damping must be incorporated in the design.

xi AESTHETICS. Consideration must often be given to minimising the impact of the structure on the environment.

Estimating Wind Speeds and Loadings

The estimation of wind speeds and loadings has been the subject of much research and international discussion during the last few years. A BSI Code of Practice for the Design of Lattice Towers is in course of preparation and is due to be issued shortly.

At present, however, BSI Code of Practice CP3 Chapter V incorporates the criteria generally used and

defines among other things the effect on loading of:

a observed wind speeds for the area concerned
b the gust period and frequency
c shape of object in wind
d height of object above ground level
e degree of shielding from other objects
f the topography of the surrounding land
g acceptable risk of failure

The design wind speed is therefore the basic wind speed modified by a series of factors reflecting some of the above conditions, while the effective area of a body is the actual projected area modified by a similar series of conditional factors.

The relationship between mean hourly wind speeds and a short gust is one of statistical observation and, for aerial support structures, the three-second criterion is taken as being the minimum time in which a structure could respond to an applied load.

GLOSSARY OF TERMS

Beam. A structural member, usually mounted horizontally, and relying on its rigidity for carrying loads between its points of support.

Bending Moment. The effect of forces in a member or composite structure causing a tendency for two parallel cross-sectional planes in that structure to incline with respect to each other.

Bracing. A horizontal or inclined member of a lattice which mainly distributes shear forces within the structure.

Cantilever. A structure, or structural member, to which load is applied beyond its points of support.

Compression. The tendency produced by an applied load for a cross-sectional plane in a body to move in a normal direction towards a parallel plane.

Deflection. Angular or linear displacement of a structure from its design shape.

Drag. A force on a structure due to wind and which acts in the direction of the wind.

Gusset Plate. A shaped flat steel plate used as a connection between two or more members in a lattice.

Leg. A main vertical, or near vertical, member of a lattice which mainly distributes bending and deadweight forces to the foundations.

Lift. A force on a structure caused by wind but which acts at right angles to the wind direction.

Redundant. A secondary member of a lattice which does not carry structural load but aids the rigidity (and thus increases the load-bearing abilities) of leg and bracing members.

RSA. Rolled-steel angle (L section). The edge formed by the angle between the two flanges is known as the heel, whereas each of the two open edges is known as a toe.

RSC. Rolled-steel channel ([section), comprising two flanges and a webb.

RSJ. Rolled-steel joist (I section), also comprising two flanges and a webb.

Shear. The tendency for a plane body to move parallel to an adjacent plane due to an applied load.

Slenderness Ratio. The ratio of the length to the cross-sectional property (the radius of gyration) of a structure, or a structural member, which is a measure of its tendency to buckle under compressive load.

Stirrup. An anchorage incorporated in a concrete foundation for the attachment of rigging, etc.

Strain. The extension per unit length of a structural member under load (conventionally positive for tension, negative for compression).

Stress. The force per unit cross-sectional area present in a structural member under load.

Tension. The tendency due to an applied load for a plane in a body to move in a normal direction away from a parallel plane.

Torsion. The tendency due to an applied load for a plane in a body to twist parallel to an adjacent plane.

UB. Universal Beam. A standard I-shaped rolled-steel section.

UC. Universal Column. A standard H-shaped rolled-steel section.

Young's Modulus. Also known as Elastic Modulus. A measure of the elasticity of a material. For any uniformly cross-sectional member under load it is defined as

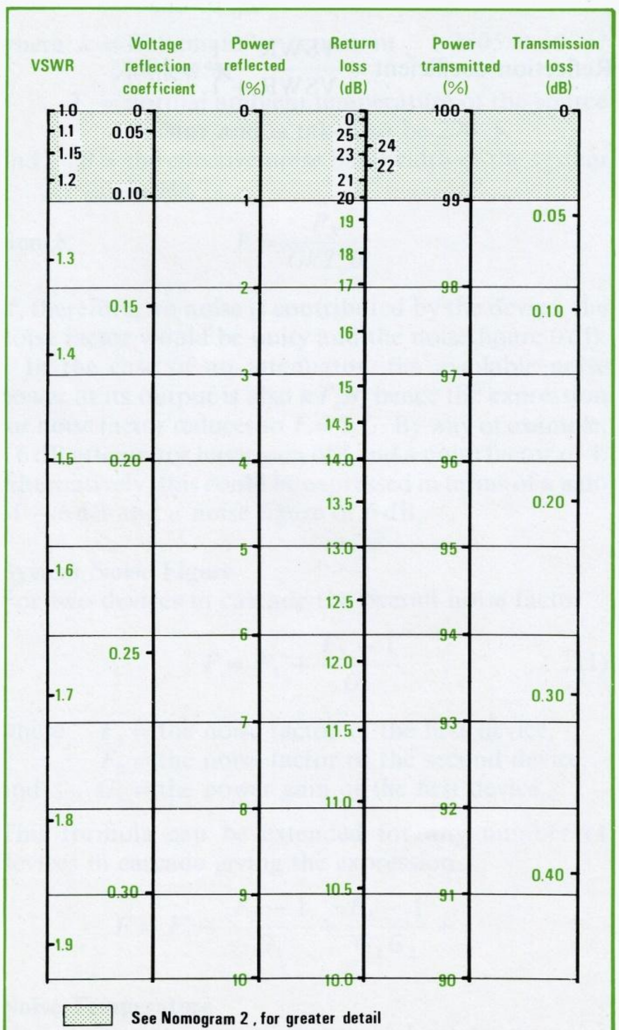
$$E = \frac{\text{stress}}{\text{strain}}.$$

Typically, for both mild and high-tensile steel,

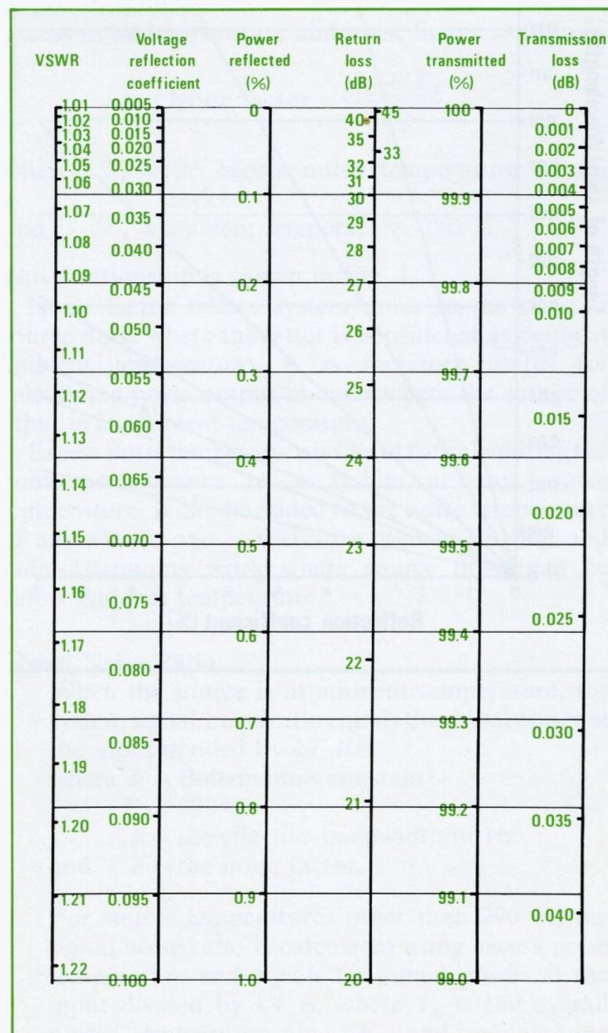
$$E = 30 \times 10^6 \text{ lbs/in}^2$$
$$= 21 \times 10^{10} \text{ N/m}^2.$$

VOLTAGE STANDING-WAVE RATIOS

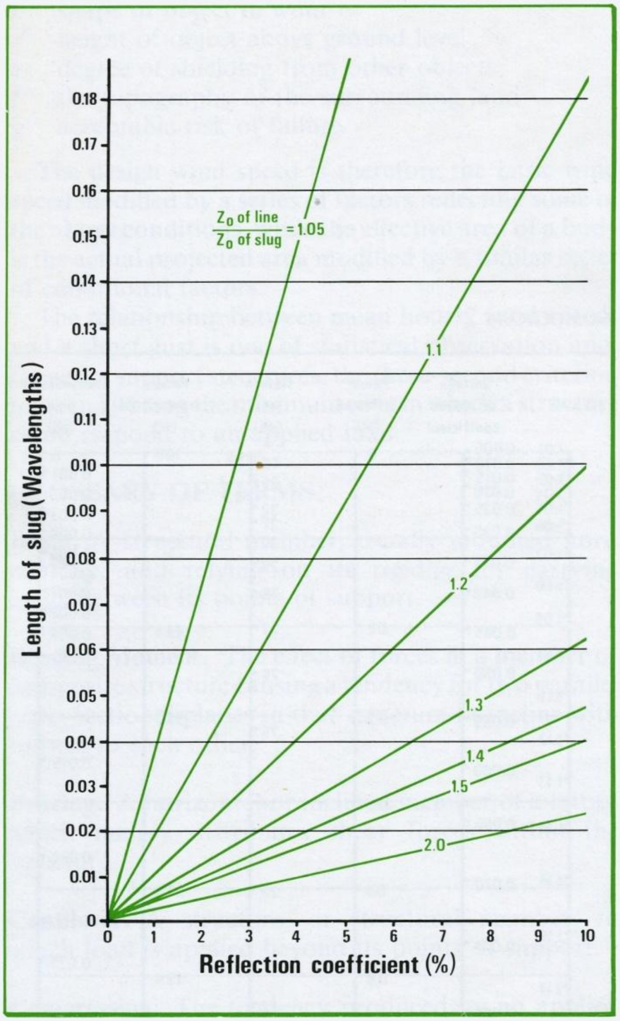
NOMOGRAM 1



NOMOGRAM 2



RELATIVE LENGTH OF CAPACITIVE STUB REQUIRED TO MATCH A TRANSMISSION LINE



The characteristic impedance, Z_0, of a coaxial line

$$= \frac{138}{\sqrt{k}} \log_{10} \frac{D}{d},$$

where D = diameter of outer conductor
d = diameter of inner conductor
and k = average dielectric constant (permittivity) of the insulating material.

The voltage standing wave ratio (VSWR) of line

$$= \frac{\text{terminating impedance}}{Z_0 \text{ of line}}$$

$$\text{Reflection coefficient} = \frac{\text{VSWR} - 1}{\text{VSWR} + 1} \times 100\%.$$

Noise—Definitions and Measurement

Noise Figure

The noise figure of any device, active or passive, is its noise factor expressed in decibels.

Consider a device with its input connected to a resistor equal in value to that of the theoretical source resistance. Then, the noise factor, F, equals the available noise power, P_N, at the output, divided by the product of the power gain, G, and the available noise power of this resistance at normal ambient temperature. The available noise power of this resistance is kT_aB watts,

where k = Boltzmann's constant $1{\cdot}3805 \times 10^{-23}$ joules/°K
T_a = normal ambient temperature of the source resistor and is taken to be 290 °K
and B = the effective noise bandwidth of the system in Hz.

Hence, $$F = \frac{P_N}{GkT_aB}.$$

If, therefore, no noise is contributed by the device, the noise factor would be unity and the noise figure 0 dB.

In the case of an attenuator, the available noise power at its output is also kT_aB, hence the expression for noise factor reduces to $F = 1/G$. By way of example, a 6 dB attenuator has a gain of $\frac{1}{4}$ and a noise factor of 4. Alternatively, this could be expressed in terms of a gain of −6 dB and a noise figure of 6 dB.

System Noise Figure

For two devices in cascade the overall noise factor

$$F = F_1 + \frac{F_2 - 1}{G_1}, \quad \ldots \quad (1)$$

where F_1 = the noise factor of the first device,
F_2 = the noise factor of the second device,
and G_1 = the power gain of the first device.

This formula can be extended for any number of devices in cascade giving the expression,

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots$$

Noise Temperature

Noise temperature is a concept which relates the noise power available at the source of a system with the temperature in °K of a resistance from which the same thermal power is available. This thermal power is given by kTB, where T is the source noise temperature.

Excess Noise Temperature

If the input of a system or device of power gain G is considered to be connected to a noise-free source, the excess noise temperature of the device is the available noise power at its output divided by GkB.

For any given device a relationship exists between its excess noise temperature and noise factor as follows:

$$\text{Noise factor} = \frac{T_E + T_A}{T_A},$$

where T_E = the excess noise temperature of the device
and T_A = ambient temperature, 290 °K

This relationship is shown in Fig. 1.

Noise factor relates system noise to the resistive source noise where the latter is considered as being at ambient temperature. It is therefore useful for calculating noise output in cases where the source of input is at ambient temperature.

Excess noise temperature is useful for calculating the noise performance of a system at any source temperature. It can be added to the noise temperature of any source and is therefore used in satellite and radio-astronomy work where source noise can be below ambient temperature.

Signal/Noise Ratio

a When the source is at ambient temperature, the system signal/noise ratio equals the signal power at the input divided by kT_aBF,
where k = Boltzmann's constant
T_a = 290 °K
B = the effective bandwidth in Hz
and F = the noise factor.

b For source temperatures other than 290 °K, the signal/noise ratio is calculated using excess noise temperature and equals the signal power at the input divided by kT_0B, where T_0 is the overall noise temperature in °K and equals the

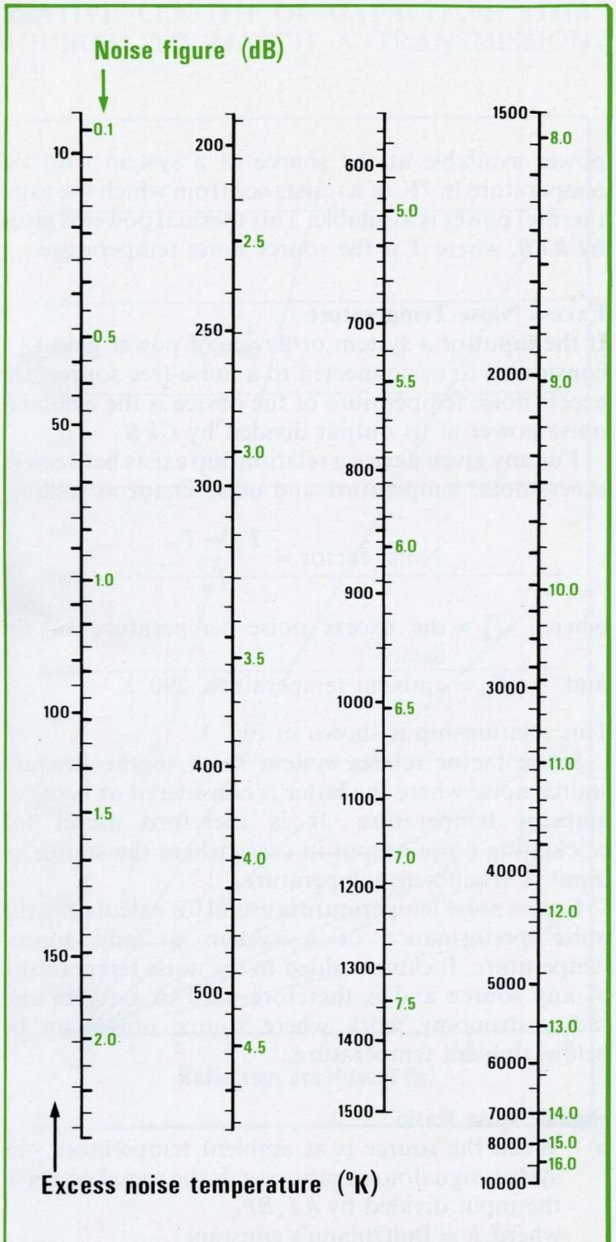


Fig. 1. Relationship between noise figure and excess noise temperature.

temperature of the source plus the excess noise temperature of the system.

The noise factor of a mixer is equal to its loss multiplied by its noise temperature ratio. The overall noise factor of mixer plus i.f. amplifier can then be calculated from the expression:

$$F = L_c N_r + L_c(F_{if} - 1) = L_c(N_r + F_{if} - 1),$$

where L_c = conversion loss of the mixer
and N_r = noise temperature ratio of the mixer, and is the ratio by which its noise factor exceeds its loss.

By comparing this expression with (1) it will be seen that $L_c N_r$ is equivalent to F_1, the noise factor of the mixer, and the loss in the mixer, L_c, is equivalent to $1/G_1$.

If the mixer is preceded by an amplifier an image filter must be placed between amplifier and mixer to suppress image noise which could double the noise contribution from the wanted channel.

Noise Figure Measurement

Noise figure is measured by connecting a calibrated broad-band noise source through low-attenuation cables to the input of the device under test and noting the output, using an RMS voltmeter, first with the noise input set to a minimum in order to determine the ambient level, and second with the source noise increased to double the original output noise power. The noise figure in dB is then read directly from a meter on the noise generator.

It is important to note that in the case of a mixer preceded by an amplifier, the inclusion of a good quality image filter, which as already mentioned forms part of any practical system, is undetected since, with this method of measurement, very similar results are obtained even if the filter is removed. This is because the method is essentially a 'difference' method, and the ambient noise content, though it will be approximately 3 dB more without a filter, cancels between the two voltmeter readings in each case.

If, for any reason, the filter is of poor quality, or omitted altogether, this method of noise figure measurement will yield a misleadingly optimistic result.

Base-band Measurements

For the measurement of the noise present on video signals (System I) and on audio signals within a studio complex and the interconnecting studio/transmitter network, the IBA adopts the following procedures. These are fully described, together with methods used for the measurement of other waveform parameters, in *IBA Technical Review 2, Technical Reference Book* to which reference should be made for further details.

Video Noise

a CONTINUOUS RANDOM NOISE

The signal/noise ratio for continuous random noise is

defined as the ratio expressed in decibels of the nominal p-p amplitude of the picture luminance signal to the rms amplitude of the noise measured under the following conditions:

—the noise is passed through a specified bandpass filter to delineate the effective frequency range and also where appropriate through a specified weighting network or equivalent:

—the measurement is made with an instrument having, in terms of power, an effective time constant or integrating time of 1 s.

i *Unweighted*

The nominal frequency range is 7·5 kHz–5·5 MHz.

ii *Weighted Luminance**

The nominal frequency range is 7·5 kHz–5·0 MHz. The weighting network response is shown in Fig. 2. It has a

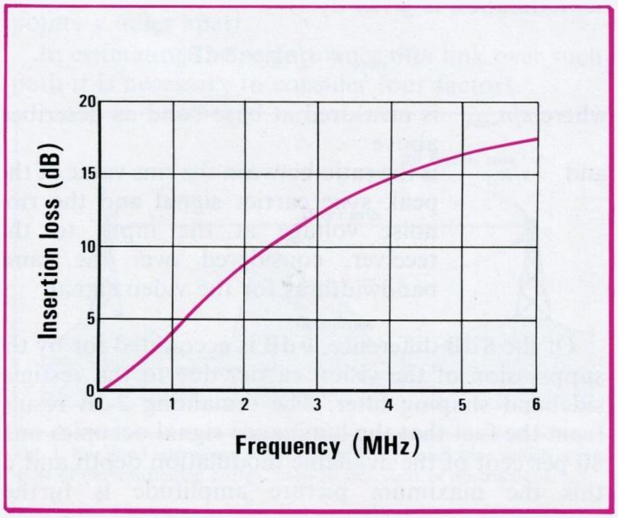


Fig. 2. Characteristic of weighting network for random noise in the luminance channel, (to CCIR Rec. 451–2). Insertion loss = $10 \log_{10} [1 + (2\pi\tau f)^2]$ dB where $\tau = 200$ ns.

time constant of 200 ns giving a weighting effect of 6·5 dB for flat random noise and 12·3 dB for triangular random noise.

Note: The CCIR specified frequency range for the measurement of the parameter is 10 kHz–5·0 MHz. The practical effect of lowering the lf limit from 10–7·5 kHz is insignificant.

* It is expected that the CCIR will shortly introduce a unified video noise weighting network which would render separate luminance and chrominance noise measurements unnecessary.

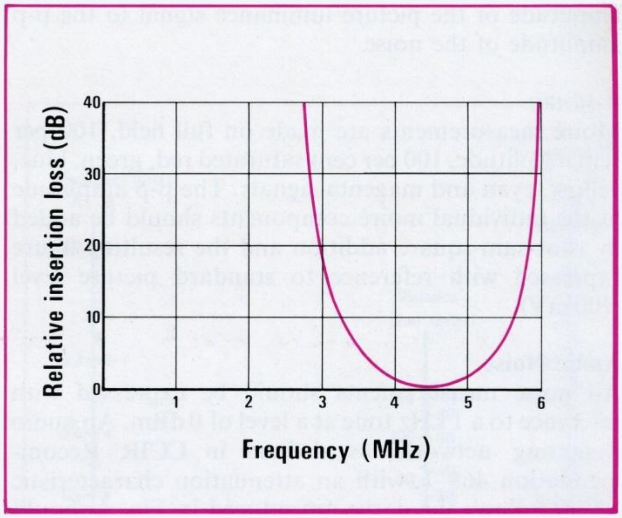


Fig. 3. Characteristic of band-pass filter and weighting network for random noise in the chrominance channel, (to CCIR Rec. 451–2).

iii *Weighted Chrominance**

The nominal frequency range is 3·5 to 5·5 MHz as shown in Fig. 3. For each sub-carrier sideband, the filter provides a weighting effect which is approximately equal to that of the luminance weighting network in the 0 to 1 MHz band.

b PERIODIC NOISE

The signal/noise ratio for periodic noise is defined as the ratio, expressed in decibels, of the nominal p-p amplitude of the picture luminance signal to the p-p amplitude of the noise, measured in the band between 1 kHz and 5·5 MHz.

c LF NOISE

The signal/noise ratio for lf noise is defined as the ratio, expressed in decibels, of the nominal p-p amplitude of the picture luminance signal to the p-p amplitude of the noise measured in the band between 40 Hz and 7·5 kHz.

d VLF NOISE

The signal/noise ratio for vlf noise is defined as the ratio, expressed in decibels, of the nominal p-p amplitude of the picture luminance signal to the p-p amplitude of the noise measured in the band between 0 Hz and 40 Hz.

e IMPULSIVE NOISE

The signal/noise ratio for impulsive noise is defined as the ratio, expressed in decibels, of the nominal p-p

amplitude of the picture luminance signal to the p-p amplitude of the noise.

f MOIRÉ

Moiré measurements are made on full field, 100 per cent amplitude, 100 per cent saturated red, green, blue, yellow, cyan and magenta signals. The p-p amplitude of the individual moiré components should be added by root-sum-square addition and the resulting figure expressed with reference to standard picture level (700 mV).

Audio Noise

All noise measurements should be expressed with reference to a 1 kHz tone at a level of 0 dBm. An audio weighting network, as defined in CCIR Recommendation 468–1, with an attenuation characteristic which follows the curve reproduced in Fig. 4 should be used. The input to the channel to be measured should be terminated.

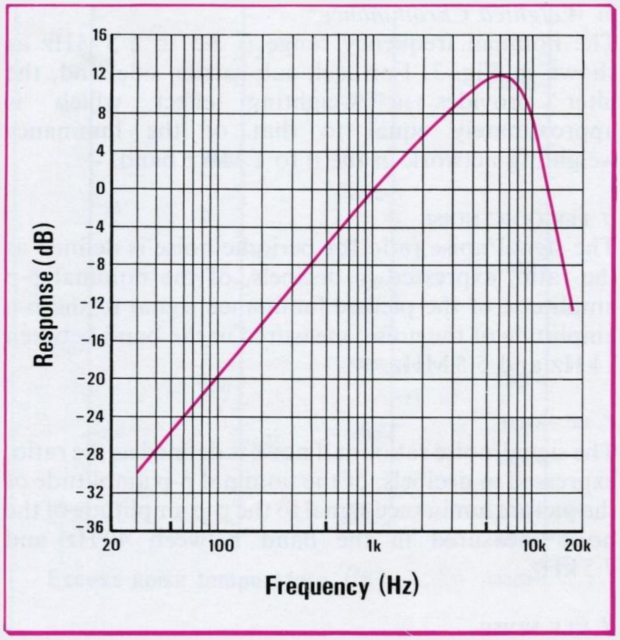


Fig. 4. Characteristic of the audio noise weighting network to CCIR Recommendation 468–1.

a WIDE BAND NOISE

Wide band noise should be measured using a peak programme meter.

b PERIODIC NOISE

Periodic noise in the band 40 Hz to 15 kHz is measured selectively and referred to zero level tone at 1 kHz measured on the same instrument.

Relationship between RF and Base-band Measurements

In the case of a television receiver the value of signal/noise ratio at its input, determined from the noise temperature or the excess noise temperature as described above, is modified by the i.f. filtering circuits and the demodulation process. The relationship between the rf signal/noise ratio at the receiver input and the signal/noise ratio of the luminance signal after demodulation is given by

$$s/n_{\text{video}} = s/n_{\text{rf}} - 8\text{ dB},$$

where s/n_{video} is measured at base-band as described above

and s/n_{rf} is the ratio between the rms value of the peak sync carrier signal and the rms noise voltage at the input to the receiver, considered over the same bandwidth as for the video signal.

Of the 8 dB difference, 6 dB is accounted for by the suppression of the vision carrier due to the vestigial sideband shaping filter. The remaining 2 dB results from the fact that the luminance signal occupies only 80 per cent of the available modulation depth and of this the maximum picture amplitude is further restricted to 70 per cent due to the inclusion of sync pulses, and that measurements at base-band are referred to peak picture signal whereas at rf the rms value of the carrier signal is used.

In the sound channel the relationship between rf input signal/noise and audio signal/noise ratios is a complex, non-linear function involving fm theory, and is beyond the scope of this volume.

Programme Links

The network of programme links used for conveying the 625-line colour television signals between the ITV programme companies and the IBA's nationwide system of transmitters is a complex mixture of microwave links either privately operated or rented from the Post Office, coaxial cable circuits and re-broadcast links. The following notes specifically feature microwave systems since these constitute a large proportion of such circuits.

Although other bands are available and in use at certain locations, the frequency band most commonly used by the IBA for analogue television links of this type extends a little above and below 7 GHz. Portable link equipment providing temporary circuits for covering outside broadcast events also uses this band.

Figure 1 shows a hypothetical link between two points x miles apart.

In estimating the performance of a link over such a path it is necessary to consider four factors.

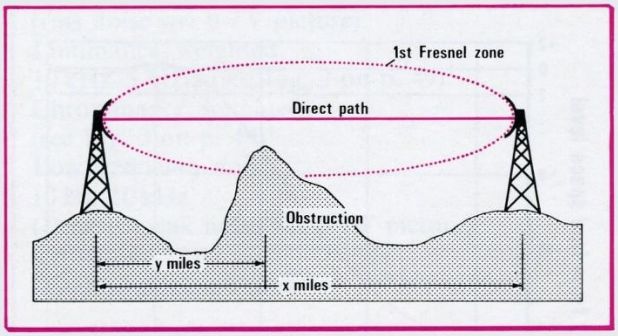


Fig. 1. For good microwave reception the first Fresnel zone, which contains most of the transmitted energy, must be well clear of obstructions.

a PATH LOSS

The free-space path loss between a transmitter and receiver x miles apart is given by the expression

attenuation between isotropic radiators

$$= 20\log_{10}\frac{\lambda}{4\pi x}$$

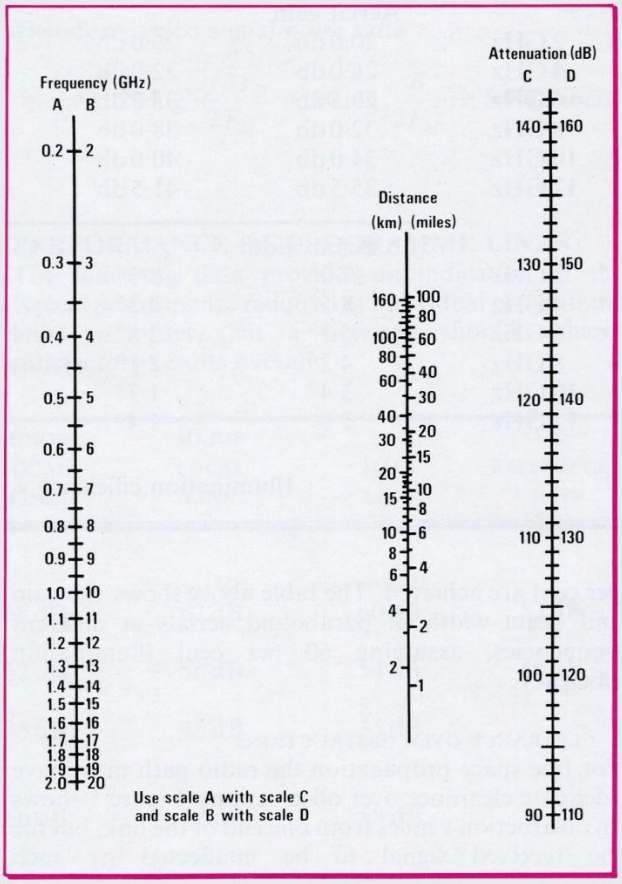
$$= 20\log_{10}\frac{1{\cdot}484\times10^{-5}}{fx}\qquad\text{decibels,}$$

where f is in GHz.

Alternatively, it can be readily found using the nomogram shown in the next column.

b AERIAL GAIN

Aerials most commonly used for microwave links have



paraboloid reflectors. The theoretical gain, G, of a parabolic reflector of area, a, relative to an isotropic source is given by

$$G = 10\log_{10}\frac{4\pi a}{\lambda^2}.$$

But for a reflector of diameter d,

$$a = \frac{\pi d^2}{4},$$

$$\therefore\qquad G = 10\log_{10}\left(\frac{\pi d}{\lambda}\right)^2\qquad\text{decibels.}$$

In fact, it is not possible to illuminate the reflector uniformly, and so the gain that can be realised in practice is limited by the efficiency of illumination. Typically, illumination efficiencies between 55 and 60

FREQUENCY	AERIAL DIAMETER 2 ft	4 ft	6 ft	8 ft	10 ft	12 ft
	Aerial gain					
2 GHz	20·0 db	26·0 db	29·5 db	32·0 db	34·0 db	35·5 db
4 GHz	26·0 db	32·0 db	35·5 db	38·0 db	40·0 db	41·5 db
6 GHz	29·5 db	35·5 db	39·0 db	41·5 db	43·5 db	45·0 db
8 GHz	32·0 db	38·0 db	41·5 db	44·0 db	46·0 db	47·5 db
10 GHz	34·0 db	40·0 db	43·5 db	46·0 db	48·0 db	49·5 db
12 GHz	35·5 db	41·5 db	45·0 db	47·5 db	49·5 db	51·0 db
	3 db Beam width					
2 GHz	17·0°	8·5°	5·7°	4·3°	3·5°	2·8°
4 GHz	8·5°	4·3°	2·9°	2·1°	1·7°	1·4°
6 GHz	5·7°	2·8°	1·9°	1·4°	1·15°	0·95°
8 GHz	4·2°	2·1°	1·4°	1·1°	0·85°	0·7°
10 GHz	3·4°	1·7°	1·15°	0·85°	0·7°	0·57°
12 GHz	2·8°	1·4°	0·95°	0·7°	0·57°	0·47°

Illumination efficiency = 60 %, beam width = $\frac{75\lambda}{d}$.

per cent are achieved. The table above shows the gain and beam width of paraboloid aerials at different frequencies, assuming 60 per cent illumination efficiency.

c CLEARANCE OVER OBSTRUCTIONS

For free space propagation the radio path must have adequate clearance over obstructions. Figure 1 shows an obstruction y miles from one end of the link, but for the received signal to be unaffected by such obstructions the first Fresnel zone of the radio path must be entirely clear. The first Fresnel zone is the locus of a point from which the sum of the distances to each link terminal is one half wavelength longer than the direct path, and its diameter varies along the length of path according to the expression $\sqrt{y(x-y)\lambda/x}$.

If this zone is not completely clear the signal will suffer attenuation in excess of the free-space value, as shown in the graph of Fig. 2. For grazing incidence of the direct beam this attenuation is 6 dB, and it falls rapidly as the obstructions obscure more of the radio path. For further details of IBA route planning for microwave links see *IBA Technical Review 7*.

d SIGNAL/NOISE PERFORMANCE

The carrier power available at the receiver input = transmitted power − path losses + aerial gains − other losses.

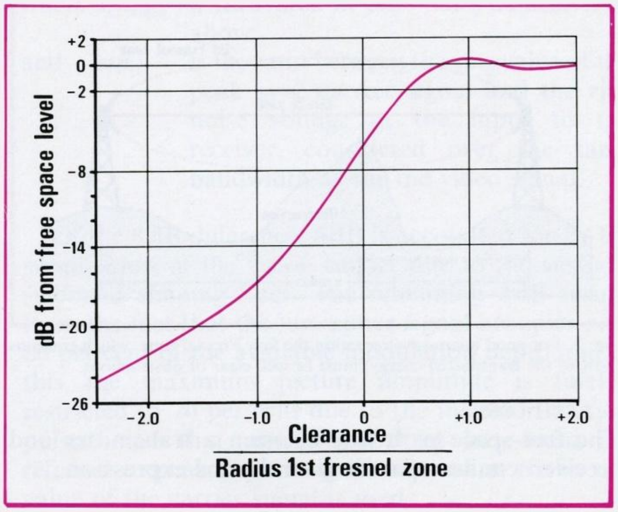


Fig. 2. As clearance over an obstruction is increased, so the received signal increases until the first Fresnel zone is unobstructed.

To calculate the signal/noise ratio at the output of the receiver it is necessary to take into account the thermal noise at the input, and the noise contributed by the receiver, i.e., noise figure, F(dB).

The thermal noise power at the input of the receiver is given by KT_aB watts, or $10\log_{10}KT_aB$ dBW, (see section on Noise—Definitions and Measurement). This thermal noise contribution is then increased by

the noise produced in the receiver. Hence, the total noise power available, referred to the input, is

$$P_N = 10\log_{10} KT_aB + F \quad \text{dBW}.$$

The signal/noise ratio at the output of the receiver can now be calculated from the ratio of the available carrier power to the available noise power, known as the carrier/noise ratio (C/N), which, for an fm system, must then be modified by three quantities as follows,

i fm improvement $= 20\log(\sqrt{3}F_D/2F_M)$,

ii bandwidth advantage $= 10\log(B/2F_M)$,

iii a factor of 5·9 dB for converting rms signal/rms noise ratio into peak-to-peak picture (0·7 V)/rms noise, as is the more usual form for expressing video signal/noise ratios,

where F_D = peak-to-peak deviation
F_M = highest modulating frequency
and B = effective rf bandwidth.

Therefore, video signal/noise ratio

$$= \frac{C}{N} + 20\log\frac{\sqrt{3}F_D}{2F_M} + 10\log\frac{B}{2F_M} + 5{\cdot}9 \text{ decibels.}$$

PERFORMANCE OF PROGRAMME LINKS

The following data provides an indication of the typical performance required of individual programme links in order that a network should achieve satisfactory results overall.

PARAMETER	MINOR LOCAL LINK	MAJOR LOCAL LINK	MAIN LINK	UK REFERENCE CHAIN
Signal/Noise Ratios				
(rms noise wrt 0·7 V picture)				
Luminance, weighted, 10 kHz–5 MHz (see Fig. 2 on p. 49)[1]	68 dB	62 dB	60 dB	52 dB
Chrominance, weighted (see Fig. 3 on p. 49)[1]	62 dB	56 dB	54 dB	46 dB
Low-frequency noise 10 Hz–10 kHz (Peak-to-peak noise wrt 0·7 V picture)	35 dB	35 dB	35 dB	—
Crosstalk (Peak-to-peak crosstalk wrt 0·7 V picture)	66 dB	62 dB	58 dB	—
Linear Waveform Distortion				
Luminance K rating	0·5 %	1 %	1 %	4 %
Luminance–Chrominance Inequalities				
Gain inequality	±0·2 dB	±0·2 dB	±0·4 dB	±1·0 dB
Delay inequality	±10 ns	±20 ns	±20 ns	±100 ns
Non-Linearity Distortion				
Line-time non-linearity	1 %	2 %	4 %	12 %
Sync-signal distortion	1 %	2 %	3 %	15 %
Chrominance–luminance crosstalk	±2 %	±3 %	±3 %	±5 %
Differential Phase and Gain Distortions				
Differential phase	±0·5°	±1°	±1°	±4°
Differential gain	±1 %	±2 %	±2 %	±8 %

Notes

1. It is expected that the CCIR will shortly introduce a unified video noise weighting network which would render separate luminance and chrominance noise measurements unnecessary.

2. Performance figures for the accompanying sound signal are given separately in the following sub-section.

Links for 625-Line Colour Television

Links used for the transmission of 625-line colour television signals between one programme company and another, and between programme companies and the IBA transmitter network are categorised by length, and in practice, different categories are frequently connected in tandem.

The three types of link are:

a main links, having a route length between 25 and 140 miles,

b major local links, having a route length less than 25 miles but including intermediate repeaters, and

c minor local links, which have a route length of less than 25 miles and do not include intermediate repeaters.

The 'United Kingdom reference chain' is defined as a network made up of four main links, two major local links and six minor local links.

Links for Monophonic Sound Transmission

Links of this type are used by the IBA for the transmission of sound signals from Independent Local Radio studios to the respective local mf transmitting stations. They are also used for conveying national news material to local radio stations, and for carrying the sound accompaniment to television programmes, but in both these cases the overall circuit is likely to be a tandem connection of several separate circuits.

The performance limits quoted here apply to each individual circuit, which may be up to 200 miles in length, and terminated at each end with a 600 ohm non-reactive impedance.

FREQUENCY RESPONSE
The amplitude-frequency response with respect to the performance at 1 kHz must be within the limits shown in Fig. 3.

NOISE
Indicated on a PPM relative to a 0 dBm test tone.

Unweighted, (50 Hz to 10 kHz) −35 dB
Weighted, −43 dB
(weighting network to
CCIR Rec. 468–1, see Fig. 4 on p. 50).

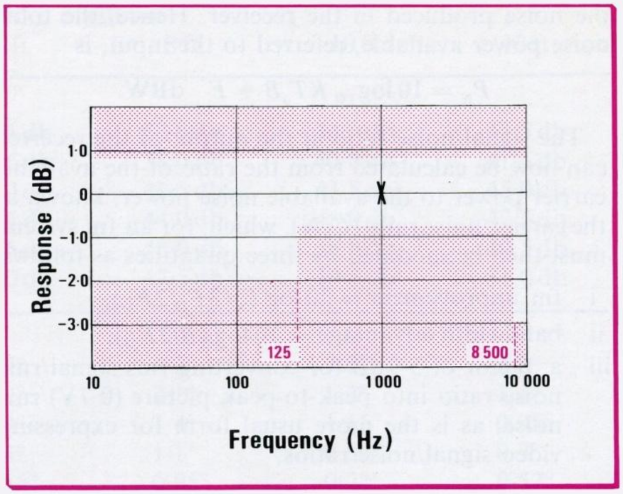


Fig. 3. Amplitude-frequency response tolerances with respect to performance at 1 kHz.

GROUP DELAY
The maximum permissible variation of group delay response is shown in Fig. 4.

HARMONIC DISTORTION
Ratio of fundamental to total harmonics

at 100 Hz $\geqslant$ 35 dB
at 1 kHz $\geqslant$ 40 dB.

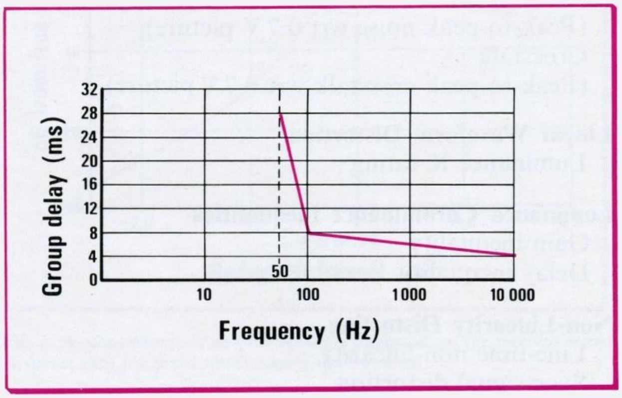


Fig. 4. Group delay characteristic.

Links for Stereophonic Sound Transmission

As used by the Independent Broadcasting Authority stereo links between ILR studios and the appropriate local vhf transmitting stations are, without exception, under 25 miles in length. Nevertheless, for the sake of completeness, performance figures are also quoted for

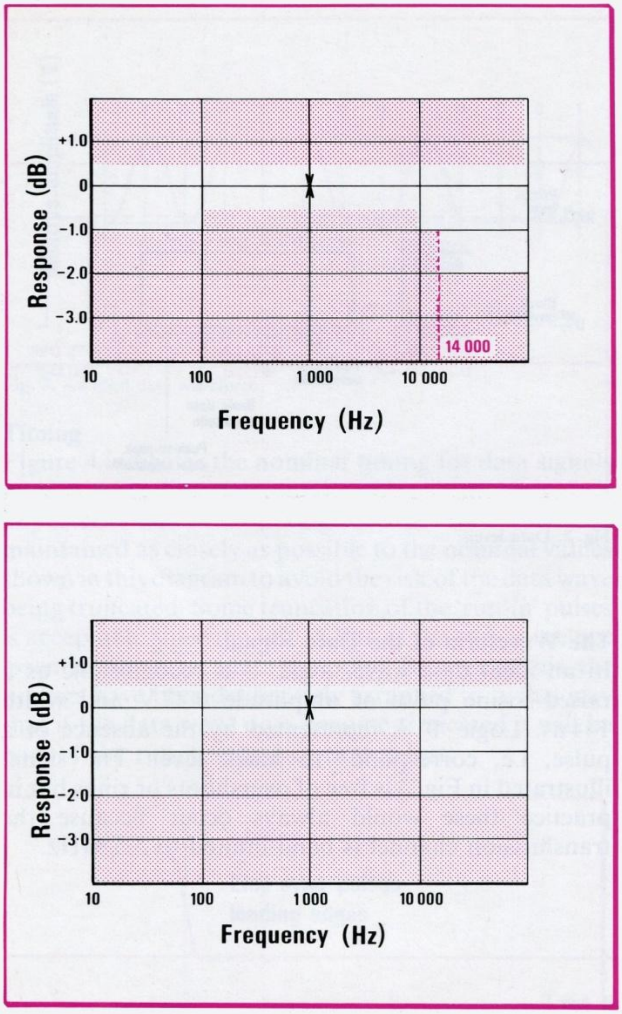


Fig. 5. Amplitude-frequency response relative to the performance at 1 kHz. The tolerances shown in the upper diagram are for circuits of less than 25 miles length, while those shown in the lower figure have been relaxed to provide for lengths of up to 100 miles.

circuits of length between 25 and 100 miles. In all cases the figures are in respect of circuits terminated with a 600 ohm non-reactive impedance at each end.

FREQUENCY RESPONSE

The amplitude-frequency response relative to 1 kHz must be within the tolerances shown in Fig. 5.

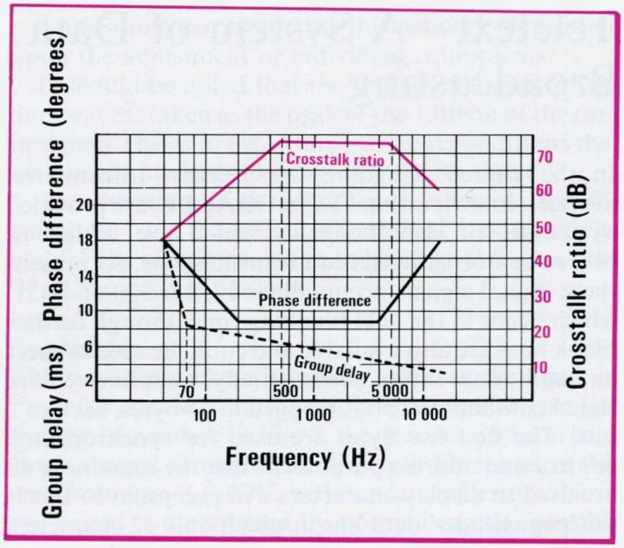


Fig. 6. Maximum permitted tolerances for group delay, and for crosstalk ratio and phase difference between the A and B channels.

NOISE

Indicated on a PPM relative to a 0 dBm test tone.

	up to 25 miles	up to 100 miles
Unweighted, (40 Hz to 15 kHz)	−44 dB	−44 dB
Weighted, (weighting network to CCIR Rec. 468–1, see Fig. 4 on p. 50).	−57 dB	−52 dB

CROSSTALK RATIO, PHASE DIFFERENCE AND GROUP DELAY

The permitted performance for these three parameters, regardless of length of circuit, is indicated in Fig. 6. The group delay at a specified frequency is the difference between the value at that frequency and the minimum value within the frequency range 40 Hz to 14 kHz.

HARMONIC DISTORTION

The total harmonic distortion, measured at 100 Hz and at 1 kHz, must be better than 50 dB.

Teletext—A System of Data Broadcasting

In the United Kingdom the Teletext Information Services, known within ITV as ORACLE, are provided by bursts of digital signals which are added to otherwise normal television transmissions. At present these digital signals occupy lines 17, 18, 330 and 331, which occur in the field blanking time, though further blank lines are also available and could be used to meet any additional future needs. Briefly, each line of data signal contains 360 bits arranged in 45 bytes, each of 8 bits. The first five bytes are used for synchronising, control and address purposes, while the remaining 40 are used to display characters. An exception to this is the 'page header' data line in which only 32 characters are displayed. For the full specification of the Teletext system reference should be made to *IBA Technical Review 2, edition 3*.

Figure 1 shows the position of the data lines used at present and their relationship to other features of the standard television signal.

The data waveform excursions are contained within the region between black level and 66 per cent of white level, but in practice allowance must be made for overshoots which will increase the peak-to-peak amplitude of the data wave. This is illustrated in Fig. 2.

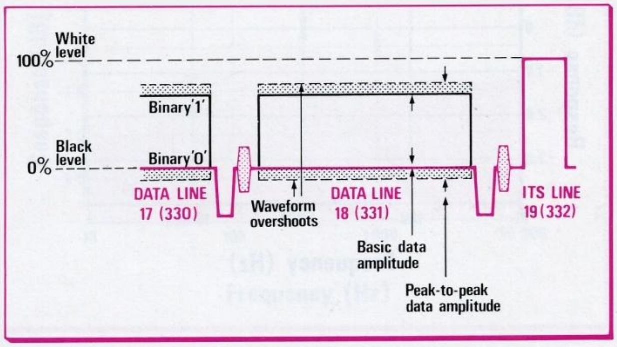


Fig. 2. Data levels.

The Waveform of the Data Signal

In an ideal data wave, logic '1' is recognisable as a raised-cosine pulse of amplitude 0·47 V and width 144 ns. Logic '0' is represented by the absence of a pulse, i.e. corresponds to black level. The signal illustrated in Fig. 3 is free of overshoots or rings but in practice these would always occur because the transmission channel is band-limited to 5·5 MHz.

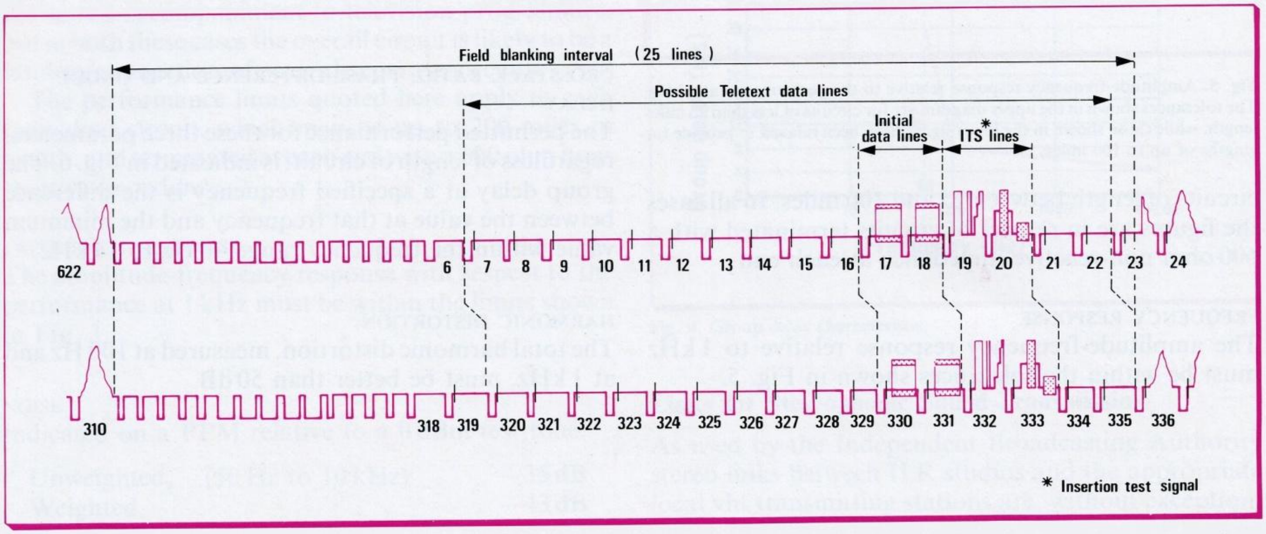


Fig. 1. Field blanking waveforms showing Teletext data lines.

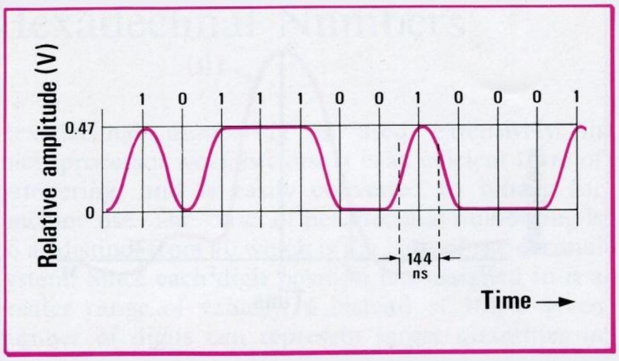


Fig. 3. An ideal data waveform.

Timing

Figure 4 indicates the nominal timing for data signals in relation to line sync and line blanking pulses. It is important that the timing of the data wave is maintained as closely as possible to the nominal values shown in this diagram to avoid the risk of the data wave being truncated. Some truncation of the 'run-in' pulses is acceptable since the full 16 bits of the run-in are not essential for correct data reception. Because of this, the timings have been deliberately arranged in such a way that if the data wave does become truncated it will be part of the run-in sequence that is lost.

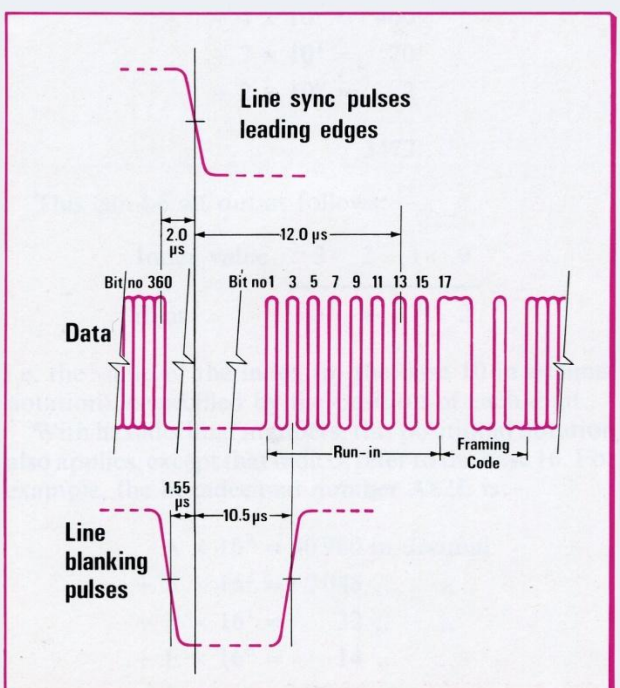


Fig. 4. Timing of the insertion data signal.

Truncation can occur on the network depending upon the adjustment of individual equipments.

It should be noted that the timing reference for the data wave is taken as the peak of the 13th bit of the run-in signal. This is to avoid any transient conditions that may occur at the beginning of the data signal.

The duration of the data wave, allowing for the transition from black level to the initial '1' of the run-in and for the return transition to black level from a final '1' of the data, is 52·04 μs.

Eye-height

The parameter which is usually taken as the figure of merit for data waveforms is known as eye-height. For the ideal data wave of Fig. 3, the decoder decision level can be varied through the full amplitude range, in this case from 0 to +0·47 V, without causing errors. Now, eye-height is determined by normalising the possible range of decision levels and expressing it as a fraction of the data amplitude, i.e. the voltage difference between the steady state values for '0' and '1'. Hence, for an ideal data wave the eye-height is unity, or 100 per cent.

An important property of an ideal data wave is that its value at any pulse-sampling instant is independent of surrounding pulses. When data is passed through a linear network having arbitrary characteristics this independence is lost and the signal is said to suffer from intersymbol interference (ISI). Where this occurs there will always be some combination of surrounding sample values which can maximally reduce the value of any logic '1' sample. In consequence, ISI always causes

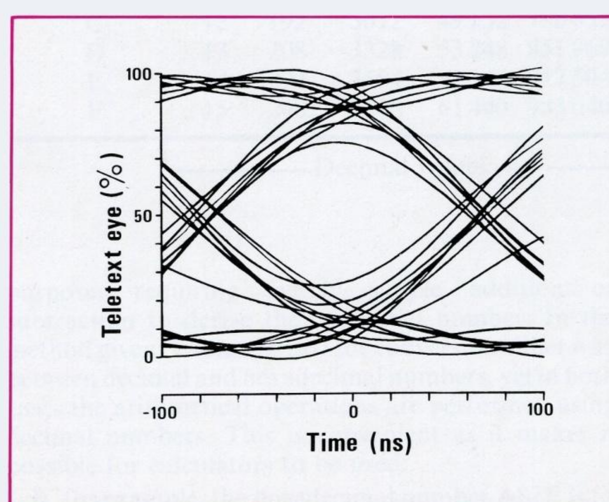


Fig. 5. An eye diagram representing an eye-height of approximately 48%.

the eye-height (and the noise margin) of the data to be less than unity.

If the voltage waveforms for successive sample periods be superimposed on the display of an oscilloscope the result might appear as shown in Fig. 5. The minimum separation between the '0' level and the '1' level assumes the characteristic eye shape which gives rise to the term eye-height.

Figure 6 shows the response of a network to a single teletext pulse. The reduction of eye-height due to the presence of ISI contributions $f(kT)$ is equal to the sum of their moduli $\sum' |f(kT)|$. It can be shown that the eye-height, h, of this system is given by:

$$h = f(0) - \sum_{k=-\infty}^{\infty}{}' \; |f(kT)|,$$

where $\sum'$ denotes summation excluding $k = 0$, and the optimum sampling time occurs at $t = 0$.

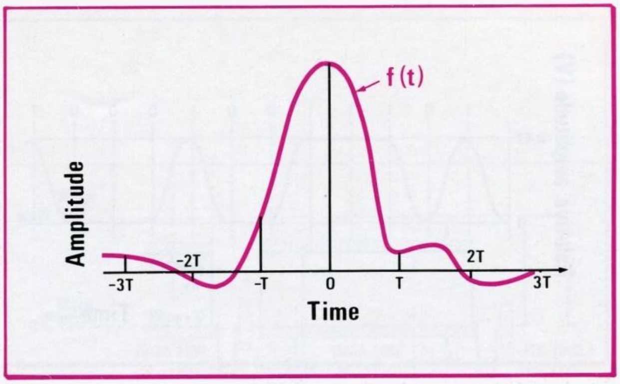


Fig. 6. The 1·44 T pulse response of a transmission channel which introduces intersymbol interference.

For further information on the subject of data quality, the reader is referred to the article entitled 'The Numerical Basis for ORACLE Transmission' in *IBA Technical Review 9*.

Hexadecimal Numbers

Hexadecimal numbering is used extensively in microprocessor work because it is an efficient form of numbering, and is easily converted to binary for machine use. The 'base' of hexadecimal numbering is 16 as distinct from 10 which is the base of the decimal system. Since each digit position has assigned to it a greater range of values (16 instead of 10), a given number of digits can represent larger quantities in hexadecimal notation than in decimal notation.

As hexadecimal counting is in multiples of 16, additional symbols are required for representing the extra six digits. The symbols used are the first six letters of the alphabet, A to F inclusive. Thus, the full range of hexadecimal digits in ascending numerical order is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F.

Construction of Numbers

All numbers are constructed as a series of digits in order of significance, e.g. the decimal number 3472 is really:—

$$\begin{aligned} 3 \times 10^3 &= 3000 \\ + 4 \times 10^2 &= 400 \\ + 7 \times 10^1 &= 70 \\ + 2 \times 10^0 &= 2 \\ \hline & \ 3472. \end{aligned}$$

This can be set out as follows:—

Index value	3	2	1	0
digit	3	4	7	2

i.e. the value of the index (to the base 10 in decimal notation) is specified by the position of each digit.

With hexadecimal numbers, this positional notation also applies, except that indices refer to the base 16. For example, the hexadecimal number A82E is:—

$$\begin{aligned} A \times 16^3 &= 40\,960 \text{ in decimal} \\ + 8 \times 16^2 &= 2\,048 \text{ ,, \quad ,,} \\ + 2 \times 16^1 &= 32 \text{ ,, \quad ,,} \\ + E \times 16^0 &= 14 \text{ ,, \quad ,,} \\ \hline & \ 43\,054 \end{aligned}$$

Conversion from Hexadecimal to Decimal

One method of conversion would be to use a list of hexadecimal numbers and their decimal equivalents. However, such a list would be exceedingly cumbersome for more than a few hundred numbers.

Using the same principles of positional notation, a more compact table can be constructed for conversion purposes requiring merely simple addition or subtraction to derive the converted number. In the method given, Table 1 is used for conversion either way between decimal and hexadecimal numbers, yet in both cases the arithmetical operations are performed using decimal numbers. This is convenient as it makes it possible for calculators to be used.

If, for example, the hexadecimal number A82E is to be converted to decimal, the following procedure is

TABLE 1. HEXADECIMAL/DECIMAL CONVERSION

HEXADECIMAL DIGIT	INDEX VALUE 0	1	2	3	4
0	0	0	0	0	0
1	1	16	256	4 096	65 536
2	2	32	512	8 192	131 072
3	3	48	768	12 288	196 608
4	4	64	1024	16 384	262 144
5	5	80	1280	20 480	327 680
6	6	96	1536	24 576	393 216
7	7	112	1792	28 672	458 752
8	8	128	2048	32 768	524 288
9	9	144	2304	36 864	589 824
A	10	160	2560	40 960	655 360
B	11	176	2816	45 056	720 896
C	12	192	3072	49 152	786 432
D	13	208	3328	53 248	851 968
E	14	224	3584	57 344	917 504
F	15	240	3840	61 440	983 040

$\underbrace{\hspace{6cm}}_{\text{Decimal values}}$

adopted. Write down the number, with index values for each digit, i.e.

index value	3	2	1	0
digit	A	8	2	E

Consider now the first digit of the hexadecimal number, i.e. A. This has index value 3, and reference should be made in Table 1 to the column for index value 3. Each decimal number listed in this column is the decimal value of the corresponding hexadecimal digit in the left hand column when ascribed to that index value. Thus, for index value 3 and hexadecimal digit A, the decimal value is 40 960. This procedure is repeated for each index value and its corresponding hexadecimal digit. The results are then added together as follows:

Index value	Hexadecimal digit	Decimal value (from table)
3	A	40 960
2	8	2 048
1	2	32
0	E	14
		43 054.

Hence, 43 054 is the decimal equivalent of the hexadecimal number A82E.

Conversion from Decimal to Hexadecimal

To illustrate the conversion from decimal to hexadecimal the previous example will be worked backwards. Starting with the decimal number 43 054, explore Table 1 to find the *largest decimal* number that is *smaller* than the number to be converted. In the case of the present example, this is 40 960. Then, the column containing this number gives the index value, 3, and the row gives the required hexadecimal digit for that index value, A.

Next, subtract the decimal number found in the table from the number being converted, i.e. 43 054 − 40 960 = 2094, and again search the table to find the largest decimal number that is smaller than the result so obtained. Once more note the index value and corresponding hexadecimal digit, which in this case are 2 and 8 respectively.

Repeat the procedure and complete the conversion as under,

Decimal number	Hexadecimal digit	Index value
43 054		
−40 960	A	3
2 094		
−2 048	8	2
46		
−32	2	1
14	E	0

thus, A82E is the hexadecimal equivalent of the decimal number 43 054.

Conversion between Hexadecimal and Binary

Hexadecimal numbers are to the base 16, which is the fourth power of 2. Binary numbers are to the base 2, and so 16 would be represented by 1×2^4, i.e. digit 1 in the position of index value 4. Thus, the full range of hexadecimal digits from 0–F inclusive can be represented by four binary digits. Moreover, since all combinations of these four digits are utilised, each and every group of four binary digits can be precisely represented by a single hexadecimal digit. The binary equivalent of each hexadecimal digit is shown in Table 2.

TABLE 2. HEXADECIMAL/BINARY CONVERSION

HEXADECIMAL DIGITS	BINARY DIGITS
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Conversion from Hexadecimal to Binary
For each hexadecimal digit, a group of four binary digits is obtained from Table 2. The full binary number can then be written immediately by cascading these binary groups in the same order as that in which the hexadecimal digits occur. For example, to convert A82E to binary,

hexadecimal digits	A	8	2	E
binary digits from Table 2	1010	1000	0010	1110,

therefore the required binary number is 1010100000101110.

Binary to Hexadecimal Conversion
Divide the binary number into groups of four digits, starting at the right-hand side (the least significant place) and, if necessary, add sufficient zeros to the left-hand end to complete the last group of four digits. Each group of four binary digits can now be identified in Table 2 and the equivalent hexadecimal digits obtained.

List of Abbreviations

The following abbreviations represent some of the principal broadcasting regulatory bodies and other organisations.

ASA	Advertising Standards Authority Limited (UK) American Standards Association (USA)
ASBU	Arab States Broadcasting Union
BBC	British Broadcasting Corporation
BBTA	British Bureau of Television Advertising
BPO	British Post Office (this abbreviation, rather than GPO, is used in international matters)
BREMA	British Radio Equipment Manufacturers' Association
BSI	British Standards Institution
CCETT	Centre Commun d'Etudes de Télévision et Télécommunications
CCIR	Comité Consultatif International des Radio Communications (International Radio Consultative Committee)
CCITT	Comité Consultatif International Télégraphique et Téléphonique (International Telegraph and Telephone Consultative Committee)
CEI	Commission Electrotechnique Internationale (also IEC)
CEPT	Conference of European Postal and Telecommunications Administration
CIE	Commission Internationale de l'Eclairage
CISPR	Comité International Spécial des Perturbations Radioélectriques (Special International Committee on Radio Interference)
CMTT	Commission Mixte CCIR/CCITT pour les Transmissions Télévisuelles (CCIR/CCITT Joint Study Group for Television Transmissions)
CMV	Commission Mixte CCITT/CCIR pour le Vocabulaire (Joint CCITT/CCIR Study Group on Vocabulary)
COI	Central Office of Information
CTA	Cable Television Association (UK)
DIN	Deutsche Industrie-Normen (German Standards Association)
DRT	Directorate of Radio Technology (Home Office)
EBU	European Broadcasting Union (also UER)
FCC	Federal Communications Commission (USA)
IBA	Independent Broadcasting Authority
IEC	International Electrotechnical Commission (also CEI)
IFRB	International Frequency Registration Board
ISO	International Organisation for Standardisation
ITCA	Independent Television Companies Association
ITU	International Telecommunications Union (also UIT)
ITV	Independent Television—a generic term covering the activities of IBA and of the UK programme contractors
JICRAR	Joint Industry Committee for Radio Advertising Research
JICTAR	Joint Industry Committee for Television Advertising Research
NBS	National Bureau of Standards (USA)
NTSC	National Television Systems Committee (USA)
OIRT	Organisation Internationale de Radiodiffusion et Télévision (International Radio and Television Organisation *Headquarters—Prague*)
PTT	Ministry of Posts and Telecommunications (various countries)
SMPTE	Society of Motion Picture and Television Engineers
TAC	Television Advisory Committee (UK)
TASC	Television Advisory Technical Sub-Committee (UK)
UER	Union Européenne de Radiodiffusion (also EBU)
UIT	Union Internationale des Télécommunications (also ITU)

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